CAP-INO Medal for Outstanding Achievement in Applied Photonics

La médaille de l'ACP-INO pour contributions exceptionnelles en photonique appliquée

Dr. Andreas Mandelis is one of the most remarkable and accomplished researchers in Canada. His 305 publications are an imposing record of achievement. He is a Fellow of the Royal Society of Canada, a Fellow of the American Physical Society, and a fellow of the S.P.I.E (the international society for optics and photonics. He is renowned in the areas of applied photonics, imaging, applications of lasers in optoelectronics, materials science and biophotonics; in particular, he is a pioneer in the development and shaping of diffusion-wave, photothermal and photoacoustic sciences and associated technologies.

His work has ranged from the eminently practical, as in the examination of dental cavities, to the profoundly theoretical. As one of the supporters of this nomination writes, "Perhaps the work I have found to be the most creative and which impresses me the most with its depth is his *J. Math Phys.* paper [*J. Math. Phys.* **26**, 2676 (1985)], where he formulated theory for the fundamental character of thermal waves. In this paper he gave elegant derivations of a Hamilton-Jacobi formulation of thermal wave physics, a thermal wave equivalent of Planck's constant, a thermal wave Schrödinger equation, an uncertainty principle for thermal waves, and the thermal wave equivalent of Ehrenfest's theorems. The concepts embodied in these thermal wave properties are analogues of what every physicist has studied in their graduate course work, except that the fields where these ideas were originally applied are classical mechanics and quantum mechanics."

The 2012 CAP-INO Medal for Outstanding Achievement in Applied Photonics is awarded to Dr. Andreas Mandelis, University of Toronto, for his seminal contributions to the field of photothermal and photoacoustic science and applications.

La Médaille de l'ACP-INO pour contributions exceptionnelles en photonique appliquée 2012 sera décernée au Dr. Andreas Mandelis, University of Toronto, pour ses contributions originales dans le domaine de la science photothermique et photoacoustique ainsi que pour ses applications.

An exemplary entrepreneur, Dr. Mandelis has founded several companies, basing their products on patents resulting from his research.

Michael O. Steinitz
St. Francis Xavier University

Interview with Andreas Mandelis, June 2012

(by Béla Joós)

BJ— I looked into your CV and there's a lot of information but very little about your personal background. You started in physics, but quickly moved onto applied research.

Recipient of the 2012 Medal / Lauréat de la médaille de 2012:

Dr. Andreas Mandelis

AM— Right. I was in mechanical and aerospace engineering but I was still working in applied physics and materials science. There was a joint program between the physics department and mechanical and aerospace departments so the courses were in physics but the thesis was in mechanical and aerospace.

BJ— Going further back, can you tell me where you were born and raised?

AM— I was born in the island of Corfu (Kerkyra), in Greece. And I was raised in Athens and then I went to the States with a full scholarship at Yale. After I finished high school, I went immediately over to the U.S. as a Fullbright scholar.

BJ— What is your connection to Canada?

AM— The connection to Canada was that at the end of my PhD I was looking for a position in the States. I was a foreign student in the U.S. and Canada appeared to me as a good employment prospect because I was married to a Canadian and I also got a research job at Bell Northern Research in Ottawa at the same time. So, it took exactly three weeks to get permanent residency in Canada. That's how I ended up in Canada.

BJ— You seemed to have had an early interest in applied and experimental type of science.

AM— Yeah but I always enjoy doing theory. The point is I've read the standard theoretical books in my physics courses as a student, I really love doing theory but I always liked to connect that to something that is going to be useful not only for my C.V. but also potentially for somebody else. I think that's the mentality of the Faculty of Engineering so I've always been an odd ball, a scientist in engineering but understanding the engineering philosophy.

"It is a great honor for me to be awarded the 2012 CAP-INO Medal for Outstanding Achievement in Applied Photonics. As a researcher in the photoacoustic and photothermal sciences, and an entrepreneur in technologies based on these sciences, this Medal is testimony of the power of applied photonics to lead to successful industrial ventures that benefit Canadian society and strengthen Canada's international competitiveness in advanced technologies."

"C'est un grand honneur pour moi de recevoir la Médaille pour réalisations exceptionnelles en photonique appliquée 2012 de l'ACP-INO. En tant que chercheur en sciences de la photo-acoustique et photothermique, ainsi qu'entrepreneur dans les technologies basées sur ces sciences, cette médaille est un témoignage de la puissance de la photonique appliquée à mener au succès des entreprises industrielles qui bénéficient à la société canadienne et renforcent la concurrence internationale du Canada dans les technologies de pointe."

BJ— You contributed to many different subjects. It would take too long to go through the list. Usually for people who do that, there is a common theme, a technique or a scientific method or something that is transferable from one subject to the other. Is this the case or are you moving from one unrelated subject to the other?

AM— It's a very good question. It's both. Basically I've always been fascinated by energy conversion processes, which is really the essence of the physics of materials, and spectroscopy. I felt that there was important physics to do and one major interest of my early work was in non-radiative physics. How do I actually get optical energy converted into thermal energy? What are the physical processes of generation of thermal and ultrasonic energy from photonic sources in condensed and gaseous matter? At the same time I decided that while I'm doing this I can really see my way to introduce novel matter interrogation techniques which could far outdo today's diagnostic methodologies because energy conversion means that we look only at the energy that is being converted. So if you look at optical processes without energy conversion we can put light into a system and measure light out. The physical process induced by light may produce a minute change in the incident energy measured by the difference between two large optical fields (input-output). This is going to be inherently insensitive compared to, let's say, conversion from light to heat or ultrasound where a signal is obtained from a zero baseline: unless there's optical absorption converting the light, there is no signal. These physical principles naturally led me to make the linkage to concepts of instrumentation and measurement science. If I can achieve detection of a physical process with one or two orders of magnitude higher sensitivity than other methods, that is where I want to be. So there is a common element to the methods I work on: normally I try to start where others leave off. I want to be able to do better than what is currently available by using methodologies that almost always are related to physical and instrumental combinations involving energy conversion.

BJ— And your book, it was on what?

AM— It was on Green functions and mathematical methods in diffusive wave physics.

BJ— That's what I'm coming to, the theoretical technique that seemed to underly everything was diffusive waves.

AM— Yes, my motto is "diffusive waves go where no light has gone before". That has been the case with my students and my own research through the years: for example, because of energy conversion, light incident on normally opaque regions does not stop at or near the surface but, converted to heat, ultrasound electrons, or simply photons of different energy, can effectively penetrate much deeper, so one can "see" phenomena well beyond the optical reach. To do that it is necessary to develop and combine instrumentation and measurement principles along with the physics. So what are these diffusive waves? They are oscillating counterparts of conventional diffusion. Why are they useful? Because they are damped in space, so we can study depth profiles of material properties; and they are everywhere! There are thermal diffusers, everybody knows that. But when thermal sources are modulated harmonically they generate thermal waves. There are electronic diffusers: optoelectronic devices involve free carriers (free carriers are diffusive entities which, upon modulation, become carrier diffusion waves). Then we also have optical scattering and diffusion in turbid media which can be modulated to produce diffuse photon waves which are extremely useful in today's biophotonic diagnostic technologies. As an example, all these diffusion-wave fields represent opportunities to take some fundamental physical ideas, and, upon energy conversion, apply them as powerful diagnostic tools to a very wide range of applications.

BJ— So what drove you from one project to another? Opportunities or one technology giving you the seeds for another one?

AM— Escalating opportunities are a challenge going from simple problems such as monitoring defects in a material, which raises the question of "how do we study this defect problem quantitatively?". So we started looking at inverse problems in diffusion waves. People have been studying inverse problems in ultrasonics, optics and other propagating wave fields, but the diffusive field is a big mathematical issue because it is ill defined and ill posed. You can get an infinity of solutions giving you the same results as the experiment does, but which solution is the right one? That's the kind of challenge that I mean, and I started building some of the mathematical tools for inverse problems in diffusion waves. You look back when some Russian mathematicians started thinking about it 50-60 years ago but they did not move away from the basic mathematics.

So my approach, which has been successful so far, has been to pair up with people in different fields where I felt I could actually move some of my techniques and have impact in their areas.

BJ— I don't have to ask you whether you're self-driven.

AM— Well yeah, I felt those directions were very satisfying to me because I saw the challenge in fields that bridge, and are relevant to, both science and engineering.

BJ— Research is increasingly of a collaborative nature, subject matters cross-discipline and technology requires an interplay of things. Are you very much a group person or are you more individually driven?

AM— I was very much driven individually maybe because that's how I felt I had full control on my research, until I discovered how much more I can do in collaboration with others and how many more opportunities arise. Because I was a techniques-based person, I could move across a spectrum of disciplines and judge where I want to see these techniques being applied. So my approach, which has been successful so far, has been to pair up with people in different fields where I felt I could actually move some of my techniques and have impact in their areas. For instance, in dentistry: I started talking to dentists, specifically to Dr. Stephen Abrams, in my own dentist's clinic, about Planck radiation and luminescence diffuse emissions from teeth, and the result of that is that we now have a company (Quantum Dental Technologies) and an international dental caries diagnostic product line ("The Canary System"), 9 or 10 years later. Then I started looking at people in the field of biosensors and their search for a noninvasive way to monitor blood glucose. Why? Because at some point I had a blood glucose test at Mount Sinai Hospital in Toronto and the key diabetes person there made me aware of the problems with measuring glucose noninvasively. This is a measurement science "Holy Grail" to this day: after thousands and thousands of papers, nobody has really been able to measure blood glucose reliably noninvasively. To me, that was a challenge. So we paired up and put forward a proposal, I got a research grant and now I'm at the end of this research with successful results.

BJ— Isn't glucose measured routinely?

AM— They do measure it but it's not easy to measure it noninvasively. The key is the noninvasive measurement of glucose so as to avoid pricking the finger time after time. There's a thick book that has been written – Optical Techniques on Glucose Diagnostics – and a business history report by John L. Smith that is available on the internet – The Pursuit of Noninvasive Glucose: "Hunting the Deceitful Turkey". This is a Holy Grail because to this day billions have been spent and companies have gone bankrupt thinking that they're going to produce an instrument but they didn't. Just about anything that can go wrong will go wrong and will interfere with the measurement of glucose! So I started looking at it from a different point of view. Now, I think I have a mid-infrared biosensor methodology based on only one vibrational band of the glucose molecule; importantly, I have my original collaborating clinical doctor and his clinic to support me.

What I'm saying is, there is this pattern. I wanted to do something about metals and cracks in fatigued metals. So there is a Canadian company that makes automotive parts. I talked to their engineer, they liked what I had to say, suddenly we found out we have a project together so that allows me to move forward in that direction. Now there are solar cell coverings.

BJ— What is the connection of metal fatigue with solar cell coverings?

AM— Oh, because we start looking at stress and all sorts of defects and cracks, at what changes the properties of a crack. You want to prevent electronic carrier diffusion from going the natural way, interacting with mechanical defects and compromising quality. So there is a link.

BJ— You did a lot of theory.

AM— I did. But that also guides the kind of work I want my students to do. I want to do the applied science, which means to me that they have to do the science at the same time as they do the engineering, that is, they have to be able to understand physically and quantitatively what they do. Just to do the experiment is not good enough.

BJ— You know that people are very concerned about research funding and the government's emphasis on transfer of knowledge to industry. You are in a strong position but are you concerned about the changes in the funding priorities? Do you see the emphasis moving towards more applied as being the right direction?

The goal has to be right, but how you get there is very important because, unless we do the fundamental work, we're only going to be very incremental and the rest of the world will be able to do much better than we can in Canada.

AM— No. I don't really think that should be the case. I think that there must be room for fundamental research that could lead to applied. That is, the goal has to be right but how you get there is very important because, unless we do the fundamental work, we're only going to be very incremental and the rest of the world will be able to do much better than we can in Canada. As an example, beyond the methods I discussed today, some of our other work is in taking concepts from radar science and importing them into imaging science. This is something other people have not done, so as a result it is non-incremental and I can see the competitive advantages. But this is basic instrumentation science combined with the physics of materials: signal generation, signal processing, instrumentation that is going to optimize your signals in different pathways. To do this, one must understand the fundamental properties of the materials under excitation, so as to be able to generate effective and sophisticated enough instruments that are needed in order to compete with the rest of the world. It is pointless to work with existing instrumentation systems, because other people have done it already. Besides, if it is simple, they have done it. We want our research outcomes to be taken up by a sophisticated industry. Sometimes, this is an issue in Canada: the lack of an industry in a particular area which can take up and commercialize the fruits of sophisticated instrumentation research. For example, we've had problems with the area of biomedical photoacoustics, because there isn't a Canadian company there to readily exploit our photoacoustic radar and our thermophotonic radar imager research. Perversely, this is because they are the products of fundamental work and several notches removed from today's market products. So it seems there are natural initial market barriers to the products of fundamental research, but this can be overcome and Canada can be competitive with government help. You've got to do the basic science; this is the only way to non-incremental international competitiveness and rise in the standards of living of Canadians.

BJ— You're at the university. Universities have their strengths and their weaknesses. Being in a university environment, are there limitations in your style of investigation?

AM— No there are none. Because being in a university, I was given the opportunity to work in areas that I wanted to. Getting the Canada Research Chair, getting the Ontario Premier's Award and the CFI – all these gave me the freedom to move in areas that otherwise I would have had to justify several times and maybe not being successful in getting them funded the first or second time around, or not at all. These acts of government "largesse" and foresight allowed me and my group to be the first to work on critical problems, so we could patent technologies and eventually end up with something along the lines I mentioned above that's beyond only just the research papers and could be good for the country. So yes, being at the university has been a great advantage.

BJ— How do you view the role of an academic in technology transfer? More and more the government is saying that we should be able to literally provide industry with almost ready to implement or manufacture or commercialize technologies. Is that a correct approach?

AM— "Ready to implement" cannot be feasible under the present conditions in Canada or elsewhere. All significant academic research is rooted in novelty. If the outcome is something incremental, it is not going to be very worthwhile because somebody has probably already commercialized it. On the other hand, for technology transfer you need to address the particular problems of an industry. In order to do that, you need to develop sound technology with the science behind the particular problem and an eventual goal to transfer it to industry. To be useful, the transfer product has to be something that the industry partner wants, and the partner has to be wise enough to know that it's not going to be ready to implement. My technology transfer experience has taught me that maybe a year or two from now, three years if things go right and the funding is there, then there is going to be a prototype and that's what industry wants. At least the industry I am working with are really looking forward to that state-of-the-art because their scientists and engineers can now go to the CEO or the VP Research and ask for support to take the technology and put it in the production line. They also appreciate the fact that this is novel and is going to be helping them compete against the world because something like that does not exist in the hands of their competition.

As an example, the imaging of cracks in green automotive parts is not feasible before you sinter them, whereas after sintering there are methods to inspect cracks. Before sintering, there really aren't any inspection tools because the scattering of conventional wave fields (optical, ultrasonic) is too much. But unless you can catch the cracks before you sinter you can waste a great deal of dollars worth of material because the parts forming machine could be faulty. If you can catch faults ahead of time saves a lot of money and effort. This is not a trivial problem. An effective solution rests with photothermal waves and involves the physics of their interaction with subsurface inhomogeneities, the scattering of diffusive fields, the inverse problem, axial resolution and the creation and capture of depth resolved images beyond the limits of depth-integrated diffusion. It's going to take three years or so to develop the sophisticated technology, so industry must work intimately with the academic in technology transfer as there is no "ready to implement" solution. We need an educated industrial establishment that understands what it takes. They need to work two-three years together, they need to help by putting cash and lots of in-kind expertise in their area; because they want the outcome. All levels of government have to offer financial support as well so as to make Canadian industry competitive. With the automotive parts project, when the technology emerges from our lab at the Center for Advanced Diffusion-Wave Technologies at the University of Toronto, the industrial partner and we, together, are going to have a quality control tool that other industries don't have and it's going to save them money while boosting their world competitiveness. This will be a fair return for the taxpayer funds that supported the research and development.

Industry must realize that many of their major problems require an intimate interaction with, and company support of, our very willing academics and a combination of the expertise of both partners toward resolving the issues within a realistic time frame.

BJ— You deal with many companies, you created your own. Do you have lessons that you can derive that would be useful for policy makers to make Canadian companies invest more in technology and developments and have a more productive partnership between universities and industry?

AM— I think Canadian companies so far have been looking for the easy way out. That is, if there is something they can use now – "ready to implement" – they gravitate toward that. In many cases they come to the universities because they know they want something they don't have and they really do like to work with academics if something good for their operations is going to come out of that. They must realize, however, that many of their major problems require an intimate interaction with, and company support of, our very willing academics and a combination of the expertise of both partners toward resolving the issues within a realistic time frame. The point being though, Canadian industry has been trained to think that the government is going to put up the majority of the money. This is not realistic especially compared to the potential financial gains to be made as a result of a technology transfer.

BJ— That's the Canadian way.

AM— That's the Canadian way. Industry has to learn that there's no such a thing as a free hamburger or "ready to implement" solutions. Academics also have to be active in pushing their agenda to get the technology out of the universities and into the hands of industry and the health sector. In fairness, governments have several arm's length organizations and programs, whether they're federal or provincial, to provide funds such as the Ontario Centres of Excellence, I2I (ideas to innovation) and CRD, for instance. These are the vehicles industries are using for much of the support they give to university research, however, they resist putting significant additional money into the project. It's hard to find good industrial partners who pay their fair share for what they get in terms of R&D from academia! But academics have to seek them out because you cannot get any serious research money in Canada unless you have an industrial partner. It is also true that industry cannot get robust solutions to science based technical problems unless it has an academic partner expert in the field. So, the need for each other is mutual and research funding dynamics should reflect this interdependence.

BJ— hat brings me to another big issue. The CAP is very much involved in lobbying the government to support basic science. They've been arguing that physics is very important for industry and technology. The government comes back to us and tells us "you know most large companies do not value academic research. We hear it from them Bombardier and others. They don't think universities are doing anything for them." What can we do to change that mentality?

AM— Here is the way I've approached this issue. Industry is basically oblivious to what research is being done in our universities and how it can help them with their very concrete issues. So, I have become basically a salesman for research and I make industrial contacts personally. To find contacts in the industrial sector I primarily contact their chief engineers because these are the people who make the technical decisions which influence their administrators. The funding people come a lot later. That's over on the other side of the gap. There's a big divide there between the technical side and the administrators. You have to convince the technical people first. In many cases, they don't really know what you're doing. So it is up to the university researcher to contact the people and make the relevance pitch, telling those engineers that "we have something that you want". But, he/she must first become aware of the company's R&D and production problems. Invariably, that "something" is going to be the result of fundamental research in an applied direction at the university. One thing academics should know is that industry demands that what is being offered, whether it's a methodology, a piece of software or hardware, it is based on solid scientific principles. My industrial partners have always relished the assurance that "the physics is sound" behind a developing technology – they won't have anything less than that. This assurance is a powerful tool working for university researchers in pure and applied sciences when teaming up with industry, as they can ensure that the scientific background is sound. This can be coupled quite intimately with engineering researchers who have appropriate technological backgrounds and the whole team can look very strong. As an example, I have been working in heat transfer as one of my disciplines within an applied photonics envelope. What does it mean? A mastery of conductive, radiative, convective heat transfer physics. Combining physics with engineering heat transfer one can see the foundations of the latter as quanta, as vibrations and phonons, as the continuum that it is between physics and engineering, a sine qua non. It takes a specific kind of individual to communicate that to the government because that individual can see the entire spectrum. So my answer to the question is, normally one sees a portion of the spectrum. I see engineers talking to industry but they may miss the arguments of soundness and the implications of the idea, the science behind it. I also see pure scientists not talking to industry because they don't have the linkages and they lack the relevance arguments to excite very applied industrial audiences. The government is the recipient of industrial reactions, so basically it doesn't see the connections to the science either that are there but are not always explicitly made.

My industrial partners have always relished the assurance that "the physics is sound" behind a developing technology – they won't have anything less than that. This assurance is a powerful tool when teaming up with industry.

BJ— OK, thank you. You are in academia. What was your prime attraction to academic life? Are you drawn to classroom teaching, or mainly research training?

AM— It's the freedom to choose what you want to do and to choose what you think is important and then you try your best. I get excited thinking "hey, I bet that what I'm doing could be important" and then I go out and work on it. A few years later I review the results as objectively as I can to see if I made the right decision to go in this direction. Also a very important aspect of academia is the freshness of continuously moving ideas that exists in the laboratory. New people, new young people with fresh minds come to me. I believe that I have learned more from my students than they may have learned from me because they come up with many fresh ideas. I don't think there's any other environment where you can talk to peers while they're your students. I think there is a lot to be said for that. In an industrial setting where I was working for a couple of years, the mind set is this: we have this task to carry out from A to Z, we have to do this within time limits and within budget. That is not very conducive to new pioneering insights, notions and things like that because there is just not enough freedom. So ultimately it is the numbers of degrees of freedom that I cherish in academia. Although classroom teaching is absolutely important because it sets the foundations of a subject, concept teaching within research training is what I enjoy the most as there are no rules there, no textbook to invoke as the final arbiter of an argument. All of our scientific knowledge and its boundaries, including the scientific literature we can cite by heart, are on the table – this is the ultimate dynamic teaching and learning platform!

BJ— One last question. You definitely must work very hard. So what do you do to relax and do you have any hobbies or your work is basically your hobby?

AM— I also work on the editorial board of about three journals over the evening and I prepare monthly "New Products" reports for "Physics Today" and the "Review of Scientific Instruments". What I do to relax is once in a while I take off to Greece. I also go on vacation elsewhere in Europe. You cannot relax while you're in Toronto, that's my feeling. You have to go elsewhere and that's exactly what I do. One of the things I do in the summertime is take off and sit at a café on the island of Corfu relaxing and working on my own research papers. I have published research papers that I conceived and wrote while sitting in a café drinking coffee. That is very relaxing to me because it's a non-pressured environment and it leads to intense intellectual activity. There's no deadline. I don't have to deliver anything to you by tomorrow and to me this is my relaxation, so every year I do this kind of thing and, yes, ultimately I don't go fishing because this is what I know how to do best and I enjoy doing it as long as I don't have to meet a deadline. It is all about changing one's environment, taking the time to think about some of the deeper aspects of the research that you want to do but you're not able to accomplish in the routine of life in Toronto because of so many other obligations and projects that must be on time and on budget. Acting on those other ideas and observing concrete outcomes is an ultimate reassurance of my individuality and self worth.

CAP-CRM Prize In Theoretical And Mathematical Physics

Le Prix ACP-CRM de physique théorique et mathématique

Luc Vinet is one of Canada's leading mathematical and theoretical physicists who has made outstanding contributions in numerous areas. The unifying feature of his research is the innovative use of group theoretical and algebraic methods, the emphasis on exact solutions of physical problems and the originality of his approach. He has made important contributions that have had great impact on both physics and mathematics.

The 2012 CAP-CRM Prize In Theoretical And Mathematical Physics is awarded to Luc Vinet, University of Montreal, for his outstanding and continued contributions to mathematical physics, mainly based on the study of symmetries, algebraic structures, and special functions.

His early remarkable work was on gauge field theories in particular on exact invariant solutions of Yang–Mills equations in Minkowski space.

Recipient of the 2012 Medal / Lauréat de la médaille de 2012:

Dr. Luc Vinet

Also early in his career he identified the symmetries and supersymmetries of magnetic monopole systems. He explored various algebraic structures appropriate to describe symmetries in different physical problems. These go well beyond standard Lie groups and algebras. They include polynomial, quantum, super- and parasuper- algebras.

Le Prix ACP-CRM de physique théorique et mathématique 2012 sera décerné à Luc Vinet, University of Montreal, pour ses contributions exceptionnelles et constantes à la physique mathématique, principalement sur l'étude des symétries, des structures algébriques et des fonctions spéciales.

He is very well known for his influential work on quantum many body problems and for his application of this work to a proof of the long outstanding Macdonald conjecture on properties of multivariate orthogonal polynomials. His contributions to the symmetry theory of difference and q-difference equations are truly pioneering. Remarkably, Vinet's scientific career was not interrupted by his heavy administrative duties as Director of the Centre de Recherches Mathematiques, then Provost of McGill University and finally Rector of the Universite de Montreal. He continued to publish highly innovative work during his administrative tenure and is now going through a new burst of creativity. Quite recently, in 2011, he has discovered new families of orthogonal polynomials, associated to reflections. These have already found many applications. In the context of quantum information theory, he has shown how spin chains can be used to design perfect quantum wires.

Pavel Winternitz
Centre de recherches mathématiques

REMARKS BY LUC VINET

SEIZED OPPORTUNITIES: A PERSONAL PRAISE OF THE CRM

I am tremendously pleased and honoured to receive the 2012 CAP-CRM medal in theoretical and mathematical physics. I would first like to thank the generous colleagues who have proposed and supported my nomination. Throughout my career I have had the good fortune of always working with friends from whom I have learned much. Let me therefore use the occasion to express to all of them, collaborators, postdocs and students, my profound gratefulness.

As it happens I had a role in the creation of the CAP-CRM medal in theoretical and mathematical physics. I received part of my training at the Centre de Recherches Mathématiques (CRM) and then had the privilege to become its director from 1993 to 1999. It gives me great pleasure to witness, especially in my field, that there is a preeminent and highly networked international community of researchers that has roots in the CRM. In 1995 it seemed a good idea to create a prize to celebrate and encourage theoretical and mathematical physics in Canada. CAP and CRM thus inaugurated jointly this award that has since been received by a number of outstanding scientists. It is an honour to now be included in their group knowing also of the many highly deserving people there are. One will understand that this prize brings together many threads in my career, is hence very special to me and that I much appreciate the « boomerang effect ».

"This award really means much to me and receiving it gives me great pleasure. I wish to thank CAP and CRM and the many who have a share in this most appreciated kudo. Cheers for mathematical physics at the CRM and in Canada!"

"Ce prix est particulièrement significatif pour moi et je suis très heureux de le recevoir. J'aimerais remercier l'ACP et le CRM ainsi que tous ceux qui ont une part dans cette marque de reconnaissance bien appréciée. Vive la physique mathématique au CRM et au Canada!"

The long marriage between physics and mathematics has had a long and fruitful history but it also had its pitfalls. In his famous Gibbs lecture entitled « Missed opportunities » (Bulletin of the American Mathematical Society, Volume 78, Number 5, September 1972), Freeman Dyson masterfully discusses « occasions on which mathematicians and physicists lost chances of making discoveries by neglecting to talk to each other ». The title I have given to this response obviously refers to this article, as I would like to briefly offer egocentric counterexamples where the CRM was directly responsible for creating the exchanges Dyson was wishing for.

My former PhD student Luc Lapointe and I are getting recognition for the proof of a version of the long-standing conjecture of Macdonald. In 1995, we were looking for exact solutions to the many-body Calogero model and had obtained raising operators for the multivariate polynomials arising in the wave functions. There was a workshop in Algebraic Combinatorics taking place at the CRM at the time. This gave us the opportunity to present our results to some participants in the meeting who quickly educated us on the conjecture and suggested that we might have a way to prove it. They were right of course. This example is a case where physics provided the tools to solve a mathematical problem.

In the summer of 2010, after much involvement in senior university management, I was making my first investigations in quantum information (QI) looking at the design of perfect quantum wires. The CRM again came to help with a QI theme semester in the following fall that brought to Montreal the experts with whom we could validate our findings.

Even in these days of interdisciplinarity, mathematical physics may find itself in an uncomfortable place being deemed « neither fish nor fowl ». Good science should not suffer from labels, fashions or cliques. Like Dyson I plea for more seized opportunities and I wish to commend the remarkable institutes like the CRM across Canada who really make them happen by judiciously bringing together scientists from various horizons.

As per the words of Wigner, exploring « the unreasonable effectiveness of mathematics in the natural sciences » is an always awe-inspiring activity and to be rewarded for it is really « icing on the cake ». My thanks again to my family, to my friends, to CAP and to the institutions that are supporting me.

CAP Medal for Excellence in Teaching Undergraduate Physics

La Médaille de l'ACP pour l'excellence en enseignement de la physique au premier cycle

It is difficult to imagine a person more deserving of the Medal for Undergraduate Teaching. David is the linchpin of our large first year teaching efforts at Toronto. With over 1000 very demanding first year biology and pre-med students, our largest courses represent a significant challenge for any teacher. Over many years, and especially in the last decade, David has taken on a leadership role in bringing modern Physics pedagogical techniques to these courses. He has relentlessly scoured the world for the best in Physics Education Research and then done the hard work necessary to roll out sweeping changes to the way we teach Physics to these students. The benefits are enormous; greatly improved student satisfaction, and a new higher profile for the department as a place for teaching innovation are just two.

The 2012 CAP Medal for Excellence in Teaching Undergraduate Physics is awarded to Dr. David Harrison, Dept. of Physics, Univ. of Toronto, for his leadership and innovation in introducing research-based pedagogical techniques to his physics courses at the University of Toronto, and for his significant contributions to the on-line physics teaching community and the Ontario Association of Physics Teachers.

La Médaille de l'ACP pour l'excellence en enseignement de la physique au premier cycle 2012 sera décernée au Dr. David Harrison, Dept. of Physics, Univ. of Toronto, pour son leadership et son esprit innovateur dans l'emploi de méthodes pédagogiques fondées sur la recherche lors de ses cours de physique à l'Université de Toronto ainsi que pour sa contribution marquante à la communauté enseignante de la physique en ligne et à l'Ontario Association of Physics Teachers.

A major part of David's work has been the complete renovation and replacement of our old first year labs and tutorials with new Physics "Practicals". These combine all the best available ideas in hands-on, experiential Physics pedagogy with new purpose-built rooms and an entirely new set of activities and labs. These innovations took several years to implement and cost more than $1 million to realize. David tirelessly drove this project from start to finish, attending to every aspect. David is also central to the suite of "Physics for Humanities" courses that we offer.

David has taught thousands of non-Physics students to appreciate and delight in Physics, as well as extensively writing on this topic. He has made his notes for students at various stages available on the web for the last decade. This collection has grown to hundreds of pages of that amounts to an online free book called The Physics Virtual Bookshelf. These documents have been consulted millions of times. He is also the author of a very large and well-regarded collection of Flash demonstrations, again freely available online. These are particularly suited for use in the classroom and are downloaded at a rate of around one million times per year.

Stephen Morris
University of Toronto

Recipient of the 2012 Medal / Lauréat de la médaille de 2012:

Dr. David Harrison

Remarks by David Harrison

It is typical for award winners, both inside and outside academia, to deflect credit to colleagues, a deity, a grandmother, etc. Often this strikes me as being disingenuous, as I sometimes get the feeling that the recipient is secretly thinking "I deserve this because I really am great." However in my case I think deflecting credit really is appropriate. I really don't have great skill as an educator, but have been fortunate to have been surrounded by great teachers. I haven't really contributed to Physics Education Research either, but have been taught a great deal about pedagogy from those who have. Of course, I have also learned a great deal by watching the results of my students suffering through my many mistakes. If I have contributed anything worthy of this medal it is perhaps, as the citation stated, my "relentless pursuit of improved teaching using new, evidence-based teaching methodologies." Relentless in this case is a synonym for "stubborn".

"This award is, of course, thrilling for me, although I suspect that my very small number of successes is due to many students through the years suffering through my many many failures."

"Ce prix est, bien sûr, excitant pour moi, bien que je soupçonne que mon nombre limité de succès soit dû à de nombreux étudiants qui, au fil des années, ont souffert à travers mes nombreux échecs."

Churchill nicely summarized my feelings here when he said that "success is going from failure to failure without loss of enthusiasm." There is at least one very positive outcome of receiving this award. Once I (finally) converted to research-based instruction some years ago, I became an outspoken advocate for it and would talk about reformed pedagogy to anybody who would listen. So, for example, I was thrilled when I heard that some physics faculty were intending to implement research-based instruction after hearing my talk at the Plenary session in Calgary this summer. Further, the publicity surrounding the award has led to a number of invited talks on this subject in both other disciplines at my university, Toronto, and at other schools. So the pool of people willing to listen to me expound about the benefits of reformed pedagogy has grown appreciably as a direct result of this medal and the accompanying publicity.

I hope that I will not waste the pedagogical "capital" that has come my way due to this prize. I am deeply grateful to CAP and especially to my colleagues who worked very hard on nominating me for this award.

CAP/DCMMP BROCKHOUSE MEDAL
LA MÉDAILLE BROCKHOUSE

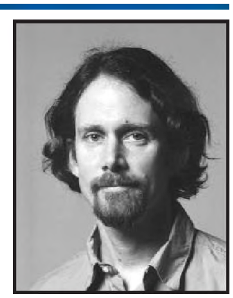
Douglas Bonn's research has focused primarily on high temperature superconductors since their discovery in 1987. Currently, this research on superconductors is equally divided between microwave and transport measurements, and sample development and preparation for a wide range of external collaborations. His work on microwave properties is in collaboration with Walter Hardy, while the work on sample preparation is performed in collaboration with Ruixing Liang. For many years Doug has been strongly involved in promoting collaborations as a means of enhancing the Canadian effort in high temperature superconductivity. The exchange of samples and ideas between the group at UBC and those at McMaster University, University of Toronto, McGill University, Université de Sherbrooke, Simon Fraser University, and many institutions outside of Canada have greatly enhanced the productivity and visibility of Canadian research in this field. In these collaborations, Doug has been intimately involved in the tailoring of samples to the particular measurement, including far-infrared, μSR, ARPES and scanning magnetic microscopy, and in the interpretation of the experimental results. He has published over 170 refereed papers, and presented many invited lectures around the world. Doug is a Fellow of the Royal Society of Canada, a Fellow of the American Physical Society, and an Associate of the Canadian Institute for Advanced Research. He has won a number of prizes including the an Alfred P. Sloan Fellowship in 1996, the CAP Herzberg Medal in 1997, an E.W.R. Steacie Fellowship and a UBC Killam Research Prize in 1999, and the UBC McDowell Medal in 2001. In 2006, the team of Bonn, Hardy and

The 2012 CAP/DCMMP Brockhouse Medal is awarded to Dr. Douglas Bonn, University of British Columbia, for his contributions to the field of high temperature superconductivity.

La Médaille Brockhouse 2012 sera décernée au Dr. Douglas Bonn, University of British Columbia, pour ses contributions dans le domaine de la supraconductivité à haute température.

Recipient of the 2012 Medal / Lauréat de la médaille de 2012:

Dr. Douglas Bonn



Liang was awarded the NSERC Brockhouse Canada Prize.

The purpose of CAP's Brockhouse Medal, which is sponsored jointly by the Division of Condensed Matter and Materials Physics (DCMMP) and the Canadian Association of Physicists (CAP), is to recognize and encourage outstanding experimental or theoretical contributions to condensed matter and materials physics. It is named in honour of Bertram Brockhouse, whose outstanding contributions to research in condensed matter physics in Canada were recognized by the 1994 Nobel Prize for Physics. The Brockhouse medal was first introduced in 1999 and has been awarded annually since.

Brian G. Turrell
University of British Columbia

REMARKS BY DOUGLAS BONN

It is an honour and a pleasure for me to be awarded this year's CAP Brockhouse medal. The name of this award brings vivid memories of the man it is named after. Bertram Brockhouse was still teaching when I was a student at McMaster. He had an early influence on me through his teaching in a second year laboratory, a memorable first exposure to real instrumentation used in research. My later upbringing as an experimentalist under Tom Timusk's supervision occurred in the materials institute that now bears Brockhouse's name. It is there that I learned two key things that continue to guide much of what I am involved in. First, the challenging problems that we work on require multiple experimental and theoretical approaches to get at the truth, so collaborations are essential to making progress. The second is that careful attention to the development of well-controlled materials is essential if one is to do good physics on those materials. This means working as closely as possible with chemists and materials scientists, preferably in an institute where they work alongside one another.

"This award is a welcome honour and one that I particularly treasure because I still have wonderful memories of my overlap with Bertram Brockhouse when I was a student at McMaster. He had an early influence on me through his teaching in a second year laboratory and my upbringing as an experimentalist occurred in the materials institute that now bears his name."

"Ce prix est un grand honneur pour moi. Il m'est particulièrement cher, puisque j'ai encore de merveilleux souvenirs de Bertram Brockhouse en tant qu'étudiant à l'Université McMaster. Il a eu très tôt une influence sur moi par son enseignement au laboratoire lors de ma deuxième année d'université; d'ailleurs, mon apprentissage comme expérimentateur a eu lieu à l'institut des matériaux qui porte désormais son nom."

In many ways I feel that I am accepting this award on behalf of a great web of collaborators. At the heart of it is my many years spent working alongside Walter Hardy and Ruixing Liang, who have been pivotal in bringing Canada to its leadership role in this field, especially through their devotion to the painstaking development of high quality single crystals and novel microwave measurement techniques to study them. This group at UBC has grown and changed over the years and I have had the pleasure of working in a great pool of talent. More broadly, there is a remarkable community effort in this field, spurred on by a collective sense that Canadian researchers can chart a highly effective course in this field through work that is based on collaboration at least as much as it is driven by competition. This began early on for us with groups not only trading samples around but also freely passing data back and forth to shed light on one another's experiments. An early example is the web of far infrared, microwave, and muon spin relaxation measurements, at UBC, McMaster and TRIUMF, that put together the story of superfluid density in the cuprates. The recent wave of exciting new results on quantum oscillations in high temperature superconductors is similarly a product of this team effort, stretching from UBC, to the group of Louis Taillefer at Univ. de Sherbrooke, and on to our international collaborators at national magnet labs. This same approach will continue to serve us well as research in condensed matter increasingly relies on large teams bringing multiple approaches to bear on difficult materials problems.

CAP-TRIUMF Vogt Medal for Contributions to Subatomic Physics

La Médaille Vogt de l'ACP-TRIUMF pour l'excellence en physique subatomique

Robert Myers is a pioneering theoretical physicist who has made extraordinarily broad and deep contributions to subatomic physics. His groundbreaking contributions span a broad range, from foundational aspects of string theory and gravitational physics to innovative advances in string cosmology, a testament to his deep physical insight and originality.

The 2012 CAP-TRIUMF Vogt Medal for Contributions to Subatomic Physics is awarded to Dr. Robert Myers, Perimeter Institute / University of Waterloo, for his outstanding contributions to advancing the frontiers of string theory and its application to theories of gravitation, black holes, and QCD.

La Médaille Vogt de l'ACP-TRIUMF pour l'excellence dans le domaine de la recherche théorique ou expérimentale en physique subatomique 2012 sera décernée au Dr. Robert Myers, Perimeter Institute / University of Waterloo, pour ses contributions exceptionnelles à repousser les frontières de la théorie des cordes et de son application aux théories de la gravitation, des trous noirs et de la chromodynamique quantique.

Myers is among the most highly-cited particle physicists of all time, whose 140 papers have attracted more than 11,000 citations to date, and have opened completely new lines of inquiry. Several of his discoveries, including the widely known 'Myers effect', are regarded as modern classics. Working in the highest scientific tradition, Professor Myers has consistently sought ways to connect theory with experiment, and many of his results have implications for current experiments.

Myers has also strengthened the wider physics community in Canada. As a founding member of the Perimeter Institute for Theoretical Physics, he has played a key role in building the institute into an internationally recognized centre of research excellence, including serving as its Scientific Director from 2007-2008. He was a founding member on the scientific advisory committee of the Banff International Research Station and serves on various international advisory and editorial boards.

Neil Turok
Perimeter Institute for Theoretical Physics

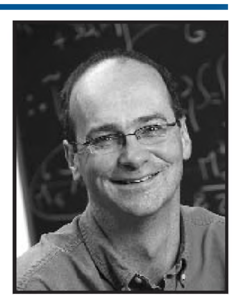
Remarks by Robert Myers

"Canada has a long tradition of research in subatomic physics and continues to be home to a vigorous community of world-class researchers in this field. Hence I am very honoured and grateful to be selected from amongst my colleagues as the recipient of the 2012 CAP-TRIUMF Vogt Medal."

"Le Canada a une longue tradition de recherche en physique subatomique et continue à rassembler une communauté vigoureuse de chercheurs de renommée mondiale dans ce domaine. C'est donc un grand honneur d'être sélectionné parmi mes collègues en tant que récipiendaire de la médaille Vogt de l'ACP-TRIUMF 2012, et j'en suis très reconnaissant."

Recipient of the 2012 Medal / Lauréat de la médaille de 2012:

Dr. Robert Myers



LAURÉATS ET GAGNANTS DE 2012

CAP Herzberg Medal

La Médaille Herzberg

Dr. Freddy Cachazo is a theoretical physicist who has made outstanding contributions to the field of particle physics, many of which are widely characterized as breakthroughs.

With collaborators, Cachazo has creatively drawn upon a variety of elegant mathematical ideas, including twistor theory, Grassmanians and algebraic geometry, to develop entirely new methods of calculating scattering processes in gauge theories and gravity. Beyond providing deep new insights into the structure of quantum field theory, these new methods have had a major impact on high-energy physics. In particular, Cachazo's techniques have become essential in state-of-the-art calculations done to interpret the new data coming from experiments at the Large Hadron Collider at CERN, as well as the Tevatron at Fermilab.

The 2012 CAP Herzberg Medal is awarded to Dr. Freddy Cachazo, Perimeter Institute, for his deep new insights into the structure of quantum field theory, and the development of elegant mathematical techniques to simplify the analysis of high-energy particle scattering experiments.

His work has already been incorporated into a textbook on quantum field theory, and his work has continued to open up entirely new research directions now being investigated all over the world. Cachazo's contributions to quantum field theory range from applications of geometric engineering (in string theory) to understanding mysterious dualities relating theories in different dimensions to improved techniques to compute scattering amplitudes in Quantum Chromodynamics (and its generalizations). In a research career spanning less than a decade, Cachazo's 41 papers have attracted well over 4,000 citations, attesting to the rapid, far-reaching impact of his new insights. The principles underlying Cachazo's research are profound. Besides being of immediate utility to huge accelerator experiments, Cachazo's works will have enduring and far-reaching impact in the search for a simpler, unified description of nature's physical laws.

La Médaille Herzberg 2012 sera décernée au Dr. Freddy Cachazo, Perimeter Institute, pour ses idées nouvelles sur la structure de la théorie des champs quantiques, et pour l'élaboration de techniques mathématiques élégantes visant à simplifier l'analyse des expériences de diffusion de particules de haute énergie.

Neil Turok
Perimeter Institute for Theoretical Physics

Remarks by Freddy Cachazo

I am very honoured to be recognized by my colleagues in Canada with the 2012 Herzberg Medal. The subject of my work goes back to Wheeler, who introduced the Scattering or S-matrix in 1937. Soon after, Heisenberg proposed to use it as a way to describe particle physics in 1942. Since then the S-matrix has become our main tool in unearthing the structure of matter and forces at very short distances.

Recipient of the 2012 Medal / Lauréat de la médaille de 2012:

Dr. Freddy Cachazo

In 1948, Feynman introduced beautiful techniques for computing S-matrix elements. Feynman diagrams are "a dream come true" as they can make manifest the two pillars of quantum field theory: unitarity and locality. However, in theories of massless particles, such as gluons, the nice properties of Feynman diagrams come with a price: a large amount of redundancy. This redundancy translates into a proliferation in the number of terms that have to be computed, so large in fact that even processes involving few number of particles can only be handled using powerful computers.

Anyone staring at a Feynman diagram might get the impression that it is telling a story of particles interacting. However, "internal lines" are very different from external particles in that they must be off the mass-shell. If the internal lines could only be made to lie on the mass-shell then the S-matrix elements could be computed using smaller S-matrix elements, thus leading to a recursion relation.

In 2004, Ruth Britto and Bo Feng, who at the time were postdoctoral fellows with me at the Institute for Advanced Study (IAS) in Princeton, joined my research in trying to use complex analysis techniques to compute scattering amplitudes. These adventures naturally led us to different space-times where internal lines can be promoted to particles, *i.e.*, can be made to lie on the mass shell! We then introduced what are now known as the BCF recursion relations.

"I am very honored to be awarded the 2012 Herzberg Medal. This medal, named after not only a brilliant scientist but also someone who had a great impact on Canada's physics community, is truly an inspiration."

Early in 2005, we developed a simple and elegant construction of the BCF recursion relations in collaboration with Edward Witten (Professor at the IAS) which is now known as the BCFW or on-shell technique. This is a good opportunity to thank Britto, Feng and Witten for a very enjoyable and exciting collaboration.

The formulas obtained using the BCF recursion relations are incredibly compact compared to those obtained using Feynman diagrams. How can it be that by allowing internal particles to wander off the space of real momenta while remaining on the mass-shell has such a dramatic impact on the form of the S-matrix?

Finding the answer to this question has motivated most of my research during recent years. In 2008, the depth of this question attracted the attention of Nima Arkani-Hamed (Professor at the IAS), one of the most influential and bright figures in particle physics. I have been very lucky to have established a very fruitful collaboration with Arkani-Hamed which has boosted this research line to a point impossible to foresee back in 2005.

"C'est un honneur de recevoir la Médaille Herzberg 2012. Cette médaille est nommée d'après non seulement un brillant scientifique, mais aussi quelqu'un qui a eu un grand impact sur le milieu canadien de la physique. Elle est vraiment une source d'inspiration."

Finally, I would like to mention that many young talented physicists have joined this research area. I have been very fortunate to collaborate with some of them and to enjoy the wonderful developments done by others. The young talents, together with pioneers of this field, who made foundational contributions in the 80's and 90's like Z. Bern, L. Dixon and D. Kosower, now compose a truly vibrant community of researchers. I would like to also dedicate this medal to the hard work and creativity of this community.

CAP MEDAL FOR LIFETIME ACHIEVEMENT IN PHYSICS
LA MÉDAILLE DE L'ACP POUR CONTRIBUTIONS EXCEPTIONNELLES À LA PHYSIQUE

Gordon Semenoff is a theoretical physicist with a long record of generating important ideas. He is internationally recognized for his 1984 pioneering work on the substance which became known as graphene. His highly cited paper, predating the fabrication of the material by 20 years, demonstrated that graphene electrons obey a Dirac equation, proposed a mechanism for giving the electron a mass, sometimes called "Semenoff mass" and applied index theorems to study the electron spectrum. These ideas were important for understanding graphene and its remarkable electronic properties once it was made in the lab. The later experimental discovery was awarded the 2010 Nobel Prize.

He is well known for contributions to quantum field theory, in particular for using mathematical index theorems to understand fractional charges and the discovery of the parity anomaly of odd-dimensional gauge theories. These ideas have had significant influence over the years and have recently come to the forefront in studies of topological insulators. His pioneering work on the real-time formulation of relativistic quantum field theories at non-zero temperature and density, including invention of the "Kobes-Semenoff rules", are considered cornerstones of that subject.

Recipient of the 2012 Medal / Lauréat de la médaille de 2012:

Prof. Gordon W. Semenoff

He has made important contributions to string theory. His computation of the Wilson loop in N = 4 Yang Mills theory is considered a classic and an important test of a duality between gauge fields and strings. His pioneering work in 2002 on string loop corrections to plane wave strings is considered seminal, not just for its results, but as the beginning of the integrability program of supersymmetric gauge theory and string theory which has been widely pursued over the ten years since.

The 2012 CAP Medal for Lifetime Achievement in Physics is awarded to Prof. Gordon W. Semenoff, University of British Columbia, for his seminal contributions to quantum field theory, statistical mechanics and condensed matter physics.

La Médaille de l'ACP pour contributions exceptionnelles à la physique 2012 sera décernée au Prof. Gordon W. Semenoff, Université de la Colombie-Britannique, pour ses contributions originales à la théorie des champs quantiques, à la mécanique statistique et à la physique de la matière condensée.

His research has earned him CAP medals in two disparate fields, the CAP/CRM Prize in Theoretical and Mathematical Physics (2000) and the Brockhouse Medal for condensed matter and material physics (2010).

Brian G. Turrell
UBC

INTERVIEW WITH GORDON SEMENOFF, JUNE 2012 (BY RICHARD MACKENZIE)

RM— Where are you born and raised, Gordon?

GWS— Pincher Creek, Alberta, about an hour from here.

RM— It makes Lethbridge look like a big city, I guess?

GWS— Yes, when I was a kid, I thought of Lethbridge as the big city.

RM— Can you describe your academic training, or in other words, your academic world line?

GWS— I studied at the University of Alberta where I got a bachelor's degree (honours physics) in 1976, and a PhD in 1981, in theoretical physics. It actually has "theoretical physics" written on the degree. I spent a little more time in Alberta; I taught a course there. After that, I was a post-doc at MIT – again in the theoretical physics group for one year. After that I moved to UBC as what was called an "NSERC University Research Fellow" which wasn't really a permanent job, but it became permanent after a few years, and I've been there ever since (since 1983 so almost 30 years).

"I am absolutely delighted to receive a CAP Lifetime Achievement Award. It is an extraordinary honour. My scientific work owes a great deal to my many co-workers, collaborators and students and I consider this award an equal acknowledgement of their talent and hard work."

RM— Who was your PhD supervisor?

GWS— My PhD was done under Hiroomi Umezawa.

RM— Over the course of your career, who influenced your choice to go into physics, your choice of area of physics, and so on? Do you have any mentors that were important to you?

"Je suis absolument ravi de recevoir la Médaille de l'ACP pour contributions exceptionnelles de carrière. C'est un honneur extraordinaire. Mon travail scientifique a été possible grâce à mes nombreux collègues de travail, collaborateurs et étudiants et je considère que ce prix constitue une reconnaissance égale de leur talent et de leur travail acharné."

GWS—I wouldn't say anybody influenced me in high school simply because there were very few people who even knew what that was. For example, I took high school calculus by correspondence since it wasn't offered at my high school; same with linear algebra.

RM— What about physics in high school?

GWS—We did have a physics course. Actually it wasn't my favourite course nor was it the one I was the best at. I was the best at chemistry with mathematics second and then physics third. But somehow physics just seemed more basic than the others. And I didn't really know what I wanted to do because I didn't know that much about these things. I just felt confident that I can do something challenging and physics and mathematics looked like the most challenging. I didn't go to chemistry. In fact, I never took another chemistry course after grade 12.

RM— Were your parents helpful in terms of your scholastic and career choices?

GWS— No. They of course wanted their kids to go to university but they discouraged areas which were less concrete and not obviously useful. They really wanted their kids to go to medicine, law or something that had an obvious place in the world.

RM— So they must have wondered where they went wrong with you!

GWS— They always worried about it, yes.

RM— Good for you for going into what you liked.

GWS— Well it was the sixties, right? I began university in 1971 so it was technically after the sixties but you still had that attitude of doing something a little bit outside the box, and going to study mathematics or physics in Alberta at the time certainly was outside the box.

My parents wanted their kids to go to university but they discouraged areas which were less concrete and not obviously useful. They really wanted their kids to go to medicine, law or something that had an obvious place in the world.

RM— Let's jump ahead a little bit to your time at MIT. I know from personal experience that you wrote a lot of papers with Antti Niemi. How did that collaboration work?

GWS— That's right. It started at MIT. You know, I don't remember how it started. Antti was there. He was a very active, brilliant guy and I just enjoyed talking to him. At the time he had a very heavy Finnish accent, and I was used to understanding accented English, partly from working with Prof. Umezawa. So I was perhaps one of the few around there who could understand what he was talking about so that made the collaboration somewhat natural.

RM— Okay. Jumping ahead again, you won the CAP-CRM Prize for Theoretical and Mathematical Physics in 2000, the CAP-DCMMP Brockhouse medal in 2010, and then this one – the CAP Medal for Lifetime Achievement in Physics. Can you remind us what you won the CAP-CRM prize for?

GWS— I think the citation was a fairly generic one for work in quantum field theory and something else I'm trying to remember.

RM— OK, it might have been string theory or something.

GWS— I wasn't very active in string theory yet at the time. The work I did in string theory that had any impact was just coming out at about that time.

RM— OK. And how about the Brockhouse medal?

GWS— That was for graphene.

RM— Graphene is an interesting story because you worked on it long before it sort of exploded internationally.

GWS— That's right. If I'd written my paper 20 years later it would have had more impact.

RM— So you wrote the paper and then it went largely unnoticed for a long time?

GWS— I would say the relatively small number of people working in the field found the paper interesting, so it was not exactly unnoticed. It was probably a fifty-citation paper until 2005-2006. Now it has near 1,000 citations according to Google Scholar.

RM— When you were doing that work did you realize that it was going to end up being so important?

GWS— Not really, at least not for a concrete reason. Theoretically the idea was very interesting, and I thought it should be important, but it only became important when a physical system it described, graphene, was discovered. There are several miracles in the case of graphene that imply that the model I used back then is basically the model that works. That didn't have to be so. The physics of graphene for electronics or even condensed matter physics is much more interesting than I anticipated it would be. It's simply because the Dirac equation in condensed matter physics gives electrons some extremely interesting properties.

RM— So in your work you studied fermions on a hexagonal lattice.

GWS— That's right, and it's a wonderful example of emergence. You get emergent special relativity and it isn't because of some complicated many-body effect which maybe wouldn't be solvable, but just single particle physics of an electron interacting with a hexagonal lattice.

RM— Amazing. Your work is very diverse. You've worked in string theory, in quantum field theory, fractional quantum numbers, condensed matter physics. The word "interdisciplinary" comes to mind.

GWS— Actually, I was always sceptical of interdisciplinarity, simply because it seemed like one spread oneself too thin in a way. To really have an impact, you have to solve a non-trivial problem. To do that you'd better concentrate on what that problem is. On the other hand, I was always taught to be broad. I think one of the first conversations I had with Umezawa when I became his graduate student had to do with this. He said something like "if you read the standard papers and do the standard calculations you'll just be a standard physicist" and that I should broaden my horizons. I think at that point I told him I was interested in quantum field theory and maybe quantum gravity, the implication being that I wasn't that interested in condensed matter physics. He was trying to convince me that I should be interested in condensed matter physics because there was really a lot of things to do there, a lot of different models and interesting physics that one could study that aren't really in the particle physics world. Particle physics really just has one model.

During one of the first conversations I had with Umezawa when I became his graduate student, he said something like "if you read the standard papers and do the standard calculations you'll just be a standard physicist". He encouraged me to broaden my horizons.

RM— But was he interested in condensed matter?

GWS— He was, yeah. In fact a lot of his program at the time was superconductivity, and some of my work with him was on superconductivity.

RM— We're now in 2012. What do you see as the big open questions in physics?

GWS— Well, this is the age of LHC. Some of these open questions could be answered just any day. Physics beyond the standard model. The hierarchy problem.

RM— Do you think we're going to find super symmetry?

GWS— You know, I think I actually signed on the positive side of a bet on that, which I regret doing because they certainly aren't seeing it right now. It looks less and less likely that they will find it at least in a way that is useful for explaining things in the standard model. That looks like it's been pushed off the map in that sense. I remain agnostic, but whatever happens there will be interesting, and I look forward to whatever that is. In fact, it could be announced this summer, at one of the big particle physics conferences.

RM— We can always take comfort in the fact that half of supersymmetry has been seen.

GWS— That's what my more skeptical colleagues in the coffee room at UBC used to say. It's a good theory. Half of the particles are already discovered.

RM— At a more pragmatic level, what's your opinion of funding in physics in particular in Canada these days?

GWS— I think compared to other jurisdictions Canada's done reasonably well even though I would say the funding is flat. One thing that has helped a lot is the private funding of the Perimeter Institute because that has injected a ton of money, both government and private money. The government money came from outside of our usual grant envelopes, so it took nothing away from us and the Institute funds quite a lot of research and does a lot of other things which has raised the profile of theoretical physics considerably in Canada. In fact, I think more has been written in newspapers about theoretical physics since Perimeter than all the integrated time before it that I can remember. So in some ways it's quite positive even though the actual funding that I would have access to has been relatively flat for quite a while.

RM— Do you see government funding being steered away from pure research towards applied research and technology and so on?

GWS— That is certainly happening. It is a directive that NSERC has gotten for example and it is one that they seem to be trying to follow through on. I wouldn't say that it's a new phenomenon entirely. I remember some pressure in that direction almost at any time in my living memory as a physicist.

RM— You've been a physics professor at UBC now for about 30 years. What do you like the most and what do you like the least about your job?

GWS— I would say the thing that I like the most is feeling I'm free to pursue whatever research seems the most promising to me. I wouldn't say I've been free to do nothing. There is pressure to produce something, but no one has ever really told me what direction I have to go in. And that freedom is invaluable. It's very difficult to make progress as it is, but if you take away the freedom to go in the most promising direction then it becomes really hopeless. So that's probably what I like the most. What I like the least? I'm drawing a blank here. When I first went to UBC it felt like a very isolated place, but it has really evolved into a major research university with almost 100% replacement of the faculty over that time. I went from being one of the youngest to one of the oldest in the space of about five years. So it was like a phase transition. So at the beginning I might have complained that I was isolated and that there wasn't a lot of help that would make myself less isolated but that seems to have gone away with time.

RM— Let's backtrack a little bit in your career. What was it like for a small town boy from Alberta to go to MIT? How did U of Alberta and MIT compare back then?

GWS— Total shock. That was the time before the Internet so there wasn't hep-th. People sent around paper preprints which had been typed on typewriters; things have really changed. At the time big groups had a big advantage in that they had all the information and they had it first, so there was quite a big difference between working in a small place and a big place. On a Canadian scale, the U of Alberta is not a small place, but on an international scale of course its particle theory group was much smaller than MIT, which had (and still has) breadth and depth. GIve a seminar at MIT and you don't really have to explain why you did what you did because the hundred people in the audience all know that already. You just have to tell them what you did.

RM— I guess there was a steady stream of famous people passing through.

GWS— Definitely. Everybody passes through at some time and it was a very big group of people more or less all interested in the frontiers of particle physics. It was actually quite a shock to be in that rather intense crowd, all very talented people. It's quite, quite different.

RM— From those days, whom do you still work with or keep in touch with regularly?

GWS— I wouldn't say I still work with anybody. I of course keep in touch with quite a few people. With some of my colleagues like Antti Niemi and Rohana Wijewardhana, with my supervisor at MIT, Roman Jackiw. In fact, he's maybe the most recent I've worked with. But I felt I learned there and as always it isn't actually learning what people did that has a permanent impact on you, it's learning how they did it just to see how people worked, the style of doing things, what the expectations were. That's the thing that has the most impact on a person.

It isn't actually learning what people did that has a permanent impact on you, it's learning how they did it just to see how people worked, the style of doing things, what the expectations were. That's the thing that has the most impact on a person.