Research statement

Michał Kotowski

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My main interest in applying to EECS MIT for a PhD program is the prospect of doing research in quantum information theory and quantum computation. I am interested mostly in mathematical and theoretical aspects of the field, although I find collaboration with more experimentally oriented researchers fruitful. The scientific work I have done so far has been not exactly in the field of quantum computation, but in a related field, namely entanglement theory and mathematical aspects of quantum information processing. In addition, I have studied basics of quantum computation both by taking courses and on my own (e. g. at the level of Nielsen's and Chuang's textbook); in October, I attended an international conference in quantum information in Stockholm and was able to get acquainted with the most recent advances in the field. I have also given talks at students' conferences on measures of quantum entanglement. I believe I am well prepared to tackle research problems in quantum information at PhD level .

At MIT I would be mostly interested in collaboration with theoretical quantum computation and information researchers from EECS and mathematics departments working on combinatorial and mathematical methods in quantum computation. These include Peter Shor, Seth Lloyd, Edward Fahri and Jeffrey Goldstone, however, I also find more physically oriented recent work by Isaac Chuang and the connections to theoretical computer science and complexity theory by Scott Aaronson interesting. I can imagine myself carrying out research in collaboration with a broad mix of mathematicians, computer scientists and physicists.

My most tangible scientific success so far was collaboration with Prof. Marek Kuś from Center for Theoretical Physics of the Polish Academy of Sciences in summer 2009 during a research fellowship. We analyzed nonclassical correlations in multipartite quantum systems, trying to put previously known entanglement measures, like 'concurrence' (originally introduced by Wootters), in a broader framework of the so-called generalized coherent states. This involved using the tools from Lie algebras theory to construct new bilinear entanglement witnesses which are, in principle, physically measurable. The general approach we have developed works for multipartite systems of an arbitrary number of distinguishable particles and bosons/fermions. Our results were summed up in the paper "Universal nonlinear entanglement witnesses", which appeared in Physical Review A in June 2010. I think that during this work I have exhibited many of the most important traits of a potential good scientist, namely perseverance, broad outlook on the problem at hand (as it was of both

mathematical and physical interest), the ability to cooperate with other scholars and build on existing results.

Another part of my research experience was participation in a research fellowship at the Weizmann Institute of Science in Rehovot, Israel, in summer 2010. The project was supervised by Prof. Vered Rom-Kedar and involved the study of of Fermi acceleration, a mathematical model originally proposed by Fermi to explain cosmic ray acceleration. Our main goal was to examine the 3-dimensional case of a model previously studied by Rom-Kedar, Turaev et al., using numerical simulations and theoretical computations. The project required extensive knowledge of dynamical systems and chaos theory, and while it did not lead to publishable results, it enabled me to see the mathematical machinery of chaos theory at work in analyzing a particular physical model. It was also an opportunity to get hands-on experience with scientific computing and simulations. The scholarship was also beneficial in other respects, giving me opportunities to talk and share experiences with leading mathematicians (e. g. in probability) and physicists (e. g. in experimental quantum information and trapped ions) at the Institute,

My current research, which is aimed towards writing an M. Sc. thesis, is supervised by Piotr Przytycki and involves analyzing spectral properties of random groups. I plan to improve a result by A. Żuk concerning Kazhdan's property for triangular groups. This is an interdisciplinary topic, involving both geometric group theory ant tools from discrete mathematics, i. e. spectral graph theory, discrete harmonic analysis and random graphs.

I have also been invited by Prof. Maciej Lewenstein from ICFO (Institute of Photonic Sciences) in Barcelona for a one month scientific stay in March-April 2011, during which I plan to work on theoretical quantum information.

Apart from purely scientific achievements, I have had much experience in educational and 'soft' scientific activities. I have tutored exceptionally gifted high school students during workshops organized by Polish Children's Fund and during independent Scientific Summer Schools, organized by University of Warsaw students. This was an excellent opportunity to gain teaching experience and look at certain subjects, like quantum cryptography or formal languages theory, from a different perspective. I have also been active in students' associations at mathematics and physics departments, organizing seminars and various events for fellow students.

I believe that pursuing a PhD degree at EECS MIT will be beneficial both to my scientific development and career, as preparing to scientific research was my priority since my high school days, and to the scientific community of quantum information theorists at MIT. I think my greatest asset will be a very broad background in all three disciplines (mathematics, computer science, physics) which meet in the field of quantum information and computation. As I have studied the basics of virtually all of important subfields of mathematics, CS and physics (from group theory to probability, from algorithms and complexity to logic, from quantum field theory to statistical physics), I feel equally comfortable working on the mathematical or the physical side of a problem. I would be happy to pursue interdisciplinary research and participate in problem solving and collaboration both with experts and fellow graduate students at EECS. As MIT is one of the leading centers in quantum computing, I

am convinced that it will provide me with an excellent environment to develop my scientific potential.