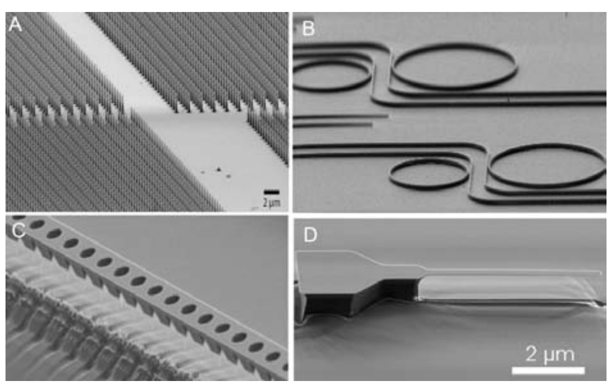
Quantum Nanophotonics and Nanomechanics with Diamond

Marko Lončar
School of Engineering and Applied Science, Harvard University, Cambridge, MA 02138, USA
loncar@seas.harvard.edu, http://nano-optics.seas.harvard.edu

Diamond possesses remarkable physical and chemical properties, and in many ways is the ultimate engineering material - "the engineer's best friend!" For example, it has high mechanical hardness and large Young's modulus, and is one of the best thermal conductors. Optically, diamond is transparent from the ultra-violet to infra-red, has a high refractive index (n = 2.4), strong optical nonlinearity and a wide variety of light-emitting defects. Finally, it is biocompatible and chemically inert, suitable for operation in harsh environment. These properties make diamond a highly desirable material for many applications, including high-frequency micro- and nano-electromechanical systems, nonlinear optics, magnetic and electric field sensing, biomedicine, and oil discovery. One particularly exciting application of diamond is in the field of quantum information science and technology, which promises realization of powerful quantum computers capable of tackling problems that cannot be solved using classical approaches, as well as realization of secure communication channels. At the heart of these applications are diamond's luminescent defects—color centers—and the nitrogen-vacancy (NV) color center in particular. This atomic system in the solid-state possesses all the essential elements for quantum technology, including storage, logic, and communication of quantum information.

I will review recent advances in nanotechnology that have enabled fabrication of nanoscale optical devices and chip-scale systems in diamond that can generate, manipulate, and store optical signals at the single-photon level. Examples include a room temperature source of single photons based on diamond nanowires[1] (Figure A) and plasmonic appertures[2], as well as single-photon generation and routing inside ring[3] (Figure B) and photonic crystal resonators (Figure C) fabricated directly in diamond[4]. In addition to these quantum applications I will present our recent work on diamond based on-chip frequency combs, as well as diamond nanomechanical resonators (Figure D).



1. T.M. Babinec, B.M. Hausmann, M. Khan, Y. Zhang, J. Maze, P.R. Hemmer, M. Lončar, "A bright single photon source based on a diamond nanowire," *Nature Nanotechnology,* 5, 195 (2010)
2. J.T. Choy, B.M. Hausmann, T.M. Babinec, I. Bulu, and M. Lončar, "Enhanced Single Photon Emission by Diamond-Plasmon Nanostructures.," *Nature Photonics,* **5**, 738 (2011)
3. B.J.M. Hausmann, et al, "Integrated Diamond Networks for Quantum Nanophotonics", *Nano Letters,* **12**, 1578 (2012)
4. M.J. Burek, et al, "Free-standing mechanical and photonic nanostructures in single-crystal diamond", *Nano Letters*, 12, 6084 (2012)

Marko Lončar is Tiantsai Lin Professor of Electrical Engineering at Harvard's School of Engineering and Applied Sciences. He received his Diploma (1997) from University of Belgrade (Republic of Serbia) and his MS (1998) and PhD (2003) degrees from California Institute of Technology, all in electrical engineering. His recent research interests include optical nanocavities, diamond nanophotonics and quantum optics, nanoscale optomechanics, and cavity-based bio-chemical sensing. Dr. Loncar is recipient of NSF CAREER Award in 2009, and Alfred P. Sloan Fellowship in 2010.