Integrated Neurophotonics: Toward Massively-Parallel, Multi-Physical Interrogation of Brain Activity

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Although our understanding of the properties of individual neurons and their role in brain computations has advanced significantly, we are still far from elucidating how complex *assemblies* of neurons interact to process information. In 2011, six U.S. scientists from different disciplines banded together, outlined a vision [1], and managed to convince the Obama administration of the unprecedented opportunity that now exists to launch a coordinated, large-scale effort to map brain activity. This culminated in the U.S. BRAIN Initiative (Brain Research through Advancing Innovative Neurotechnologies), which was launched in 2013. Our perspective was predicated, in part, on the current level of maturity of diverse fields of nanotechnology that can now be coalesced to realize powerful new tools for neuroscience. I will outline some of the hopes we had and the assertions we made, survey the existing technological landscape for massively parallel mapping of brain activity, and then focus upon our own collaborative efforts toward these goals. I will highlight opportunities in the new field of integrated neurophotonics for realizing this vision – one that leverages advances in integrated nanophotonics, optical reporters and effectors for neural recording and stimulation, and our recent developments in multi-site neural nanoprobes based on silicon large-scale integration.

[1] Alivisatos A.P., Chun M., Church G.M., Greenspan R.J., Roukes M.L., Yuste R., *The Brain Activity Map project and the challenge of functional connectomics.* Neuron **74**, 970-4 (2012).

Michael Roukes is the Robert M. Abbey Professor of Physics, Applied Physics, and Bioengineering at the California Institute of Technology. His scientific interests range from quantum measurement to applied biotechnology – with a unifying theme of the development, very-large-scale integration and application of complex nanosystems to precision measurements in physics, the life sciences and medicine. Roukes was the founding Director of Caltech's Kavli Nanoscience Institute (KNI) from 2003-2006. In 2007, he co-founded the *Alliance for Nanosystems VLSI* (very-large-scale integration) with scientists and engineers at CEA/LETI in Grenoble, which maintains a $B-scale microelectronics research foundry. He then continued as co-director of Caltech's KNI from 2008 until 2013. Since then he has returned to full-time pursuit of research efforts with his group and collaborators worldwide. Concurrent with his Caltech appointment, he has held a *Chaire d'Excellence* in nanoscience in Grenoble, France since 2008. In 2011, he was one of the six scientists who initially proposed a national project to map brain activity to the White House Office of Science and Technology Policy, which catalyzed Obama's BRAIN Initiative. Among his honors, Roukes is a Fellow of the American Physical Society, a recipient of the NIH Director's Pioneer Award, and has been awarded *Chevalier* (Knight) *dans l'Ordre des Palmes Academiques* by the Republic of France.