Reading/writing your brain: Not just another micro/optoelectronic interconnect challenge

Arto V. Nurmikko
Brown University, U.S.A.

Neuroscience has made remarkable progress in understanding the machinery of the human (mammalian) brain, both at the cellular (individual neuron) and "systems" level (brain as a neural network computer). From this has emerged a fascinating contemporary technical (and ethical) opportunity and challenge for engineers/physicists: how to implement a direct and functional interconnect between the biological neural circuitry and micro/optoelectronic circuits, for creating a "brain-machine" interface for medical and other applications, including the rapidly growing field or neural prosthetics. Extrapolating to the extreme, or perhaps the absurd: can we envision connecting the brain directly e.g. to the Internet, and if so, how would we want to embark on such a journey, literally at the interface of life and physical sciences?

This presentation will selectively highlight current research which points to the prospect of an electronic/photonic communication link via chipscale, implantable recording and stimulating micro/ nanodevices to the brain. At the cellular level, for example, a single neuron acting as a nonlinear biological oscillator and an interconnected matched nonlinear microelectronic oscillator can reach a strong coupling regime which results in phenomena such as spontaneous "sleep", i.e. quenching the coupled oscillations.[1] At the neural "systems" level, advances of recording of electrical impulses from regional neuronal assemblies by microelectrode arrays implanted to the motor cortex, with signal decoding, have led to a recent demonstration of "thought-to-action" control by a paralyzed human patient of a device such as a computer cursor (mouse).[2] While the system electronics in this breakthrough are presently bulky and tether the human subject to complex lab instrumentation, work is underway to compact the electronics on a chip which directly integrates to the micro/nanoscale neural probes.[3] The ultralow power requirements associated with implanting of such chips within the brain, and telemetry of signals to the exterior of the body draw on innovations both in micro/nano electronics and photonics. Finally, as a means to input cues to the brain from external sources, application of spatio-temporally patterned stimulation directly to the cortex is being pursued by both electrical and optical means. In one recent example, genetic engineering techniques have created photoresponsive neurons in mouse brains, which can be directly triggered by (blue) light impinging on the cortex.[4] This suggests the implant of ultracompact semiconductor light emitter arrays for projecting specific excitation patterns for neural activation by predetermined encoding approaches. Brainpods, anyone?

1. I. Ozden *et al.*, *Phys. Rev. Lett.* **93**, 158102 (2004).
2. L. R. Hochberg *et al.*, "Nature and use of neural control signals", Society for Neuroscience Annual Meeting (2005).
3. Y.-K. Song *et al.*, IEEE Trans. Neural Rehab. Engineering **13**, 220 (2005).
4. E. Boyden *et al.*, Nature Neuroscience **8**, 1263 (2005).