Multifunctional neural interfaces with tapered optical fibers

Ferruccio Pisanello[1], Massimo De Vittorio[2]
[1]Istituto Italiano di Tecnologia, Center for Biomolecular Nanotechnologies, Arnesano (Lecce), Italy
[2] Department of Health Technology, Technical University of Denmark, Kongens Lyngby, Denmark
Ferruccio.pisanello@iit.it

The adoption of multimodal optical fibers to access deep brain regions has empowered the neurophotonic community to pioneer new frontiers in optically interfacing with the mammalian brain. These advancements not only enhance optical control and monitoring of neural activity but also integrate multiple capabilities into a single device, including electrophysiological and neurochemical detection. Furthermore, they accelerate the exploration of emerging optical neural interface paradigms, such as surface plasmon resonances, which are still in their early stages of development.

Within this framework, this presentation will delve into neural interfaces that leverage the synergistic combination of microfabrication, nanotechnologies and modal properties of tapered optical fibers (TFs) [1-5]. We will discuss how the wide surface area of the fiber taper enables wide-volume optical neural interfacing with deep brain regions, with depth resolution.

Leveraging the broadband nature of the optical neural implant, we will describe how visible spectral range can be employed for control and monitoring of neural activity, while the near-infrared enables to gather spontaneous Raman spectroscopy to extract relevant information on the cytoarchitecture of the mouse brain. This allows monitoring molecular alterations linked to circuit dysfunction as well as diagnostic markers of various pathologies.

Using an original two-photon lithography approach to pattern the surface of the taper, the edge of tapered fibers can be patterned to host microelectronic elements. These include electrodes for extracellular recording of neural activity, generating optrodes that can interact with the tissue with both electrical and optical signals. Resistive temperature sensors can also be integrated with the same technology, allowing to better study the effects of light radiation on neural tissue. This non-planar patterning can achieve resolutions down to a few nanometers through unconventional bottom-up nanofabrication, paving the way for the implementation of Surface Enhanced Raman Spectroscopy (SERS) and thermoplasmonics in neuroscience research.

References

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[2] D. Zheng et al., Advanced Materials 35, 2200902 (2023)
[3] L. Collard et al, Small 18, 2200975 (2022)
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[5] F. Pisano et al, Bioarxiv, https://doi.org/10.1101/2022.06.24.497456 (2022)

Figures

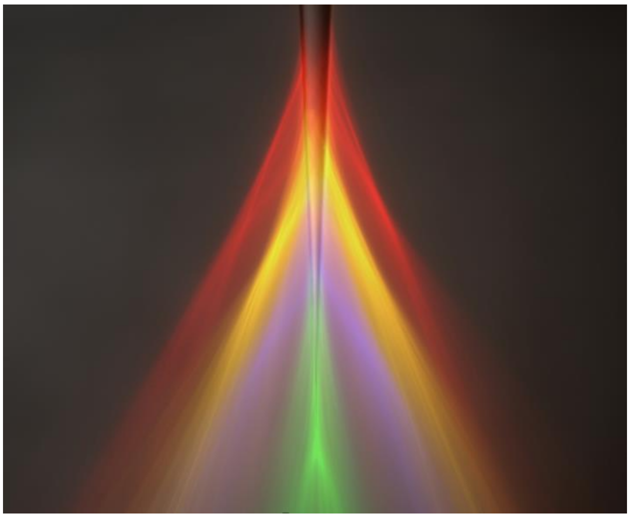

Figure 1. Example of a tapered optical fiber. False colors represent different modal subsets that can exchange energy with the surrounding environment at different section of the taper

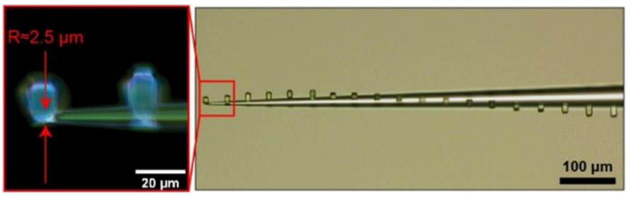

Figure 2. Example of two-photon patterning on the edge of tapered optical fibers

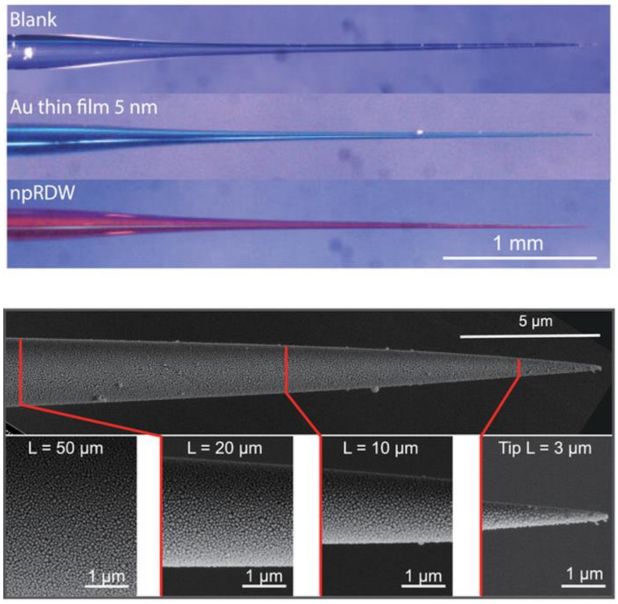

Figure 3. Nanoparticles nucleated on the tapered fiber's surface.