Study and Fabrication of Photonic Nanospikes

Letícia Magalhães*, Paulo Dainese.

Abstract
Photonic nanospikes can be used to efficiently launch light into hollow-core photonic crystal fibers (HCPFC). Mode-matching and optomechanical trapping of the nanospike (NS) at the center of the HCPFC can be achieved by a convenient design of its geometric profile. The goal of this project is to study the light propagation in silica nanowires and to develop the NS fabrication process. We optimized the structure to achieve a mechanically robust NS only 16 mm long and yet adiabatic. We have also made progress on fabrication, achieving nanospikes with 438 nm. We are working towards demonstrating the self-alignment effect.

Key words:
Optics, Fiber Optics, Optical Comunications, Photonics, Optical Forces, Self-Alignment.

Introduction
Photonic nanospikes (NS) can be used to efficiently launch light in hollow-core photonic crystal fibers (HCPFC) by simply exploring its geometric profile1. A proper design of its tip diameter, within a subwavelength regime, lead to mode-matching, strongly exciting the fundamental mode in the HCPFC. On the other hand, the fundamental mode profile in the combined structure (NS inside the HCPFC) act, by means of an optical force, trapping the NS at the center of the HCPFC. As a result, the system becomes optomechanically self-aligned and self-stabilized without the requirement of high complexity mechanical alignment. The experimental goal of this project is therefore to develop the NS fabrication process and verify experimentally the self-alignment due to optical forces. The predicted, theoretical and via computational simulations, study on light propagation in cylindrical waveguides was performed. The need for optimizing the geometry of the NS to obtain mechanical robustness led to a study on adiabaticity criteria for tapered fibers.

Results and Discussion
The fabrication process follows three steps: tapering, cleaving and etching (image 1). Special attention was given to the tapering process because it controls the shape formed by stretching a fiber in a heat source2. At this step, the diameter is tapered from 125 μm down to less than 1 μm. Therefore, the resulting shape of the transition region is strongly related to the mechanical robustness of the final NS. However, the transition must be sufficiently gradual in order to satisfy the adiabaticity criterion3.

Image 1: Fabrication steps (left) for a nanospike. SEM of the final section of a nanospike (right) with 438 nm tip diameter.

The initial samples turned out too long, difficult to handle and susceptible to laboratory noise. After performing studies on the fabrication process and on the adiabaticity criterion, we were able to find a set of performable fabrication parameters that leads to a convenient, and yet adiabatic, shape for the taper transition. The fabrication setup had to be modified in order to accept the new parameters. Furthermore, the taper is then cleaved by a simple scribe-and-tension strategy. The last millimeter of the taper halves are dipped into a 20% solution of HF in water for one minute. So far, we were able to obtain a final diameter of 438 nm.

The measurement setup (image 2) was assembled. We expect to run the experiment soon and observe that power fluctuations caused by a misalignment of the NS (due to brownian motion or laboratory noise) decrease as the input power increases. Indicating the presence of an optical force trapping the NS at the center of the HCPFC.

Image 2: Diagram of the measurement setup: laser light is amplified by a EDFA (erbium doped fiber amplifier), passing through a polarization controller and finally reaches the NS. The light then couples into a HCPFC and the transmission is measured by a photodetector.

Conclusions
A important factor for the feasibility of the experiment is the taper transition profile. Special efforts to obtain a robust geometry was performed. We were able to manufacture nanospikes with 438 nm of tip diameter.

Acknowledgement
Special thanks to LPD and CCS at UNICAMP.