

Study and Fabrication of Photonic Nanospikes

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Abstract

Photonic nanospikes can be used to efficiently launch light into hollow-core photonic crystal fibers (HCPCF). Mode-matching and optomechanical trapping of the nanospike (NS) at the center of the HCPCF 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 438nm. We are working towards demonstrating the self-alignment effect.

Key words:

Optics, Fiber Optics, Optical Communications, Photonics, Optical Forces, Self-Alignment.

Introduction

Photonic nanospikes (NS) can be used to efficiently launch light into hollow-core photonic crystal fibers (HCPCF) 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 HCPCF. On the other hand, the fundamental mode profile in the combined structure (NS inside the HCPCF) act, by means of an optical force, trapping the NS at the center of the HCPCF. 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.

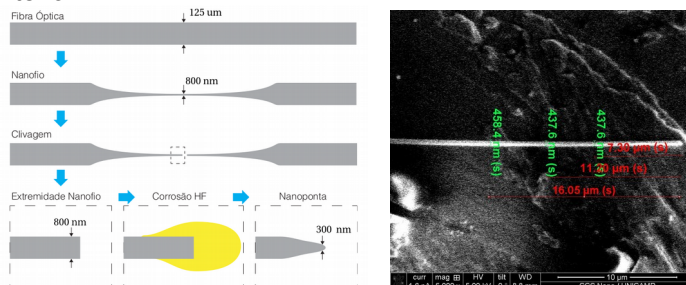


Image 1: Fabrication steps (left) for a nanospike. SEM of the final section of a nanospike (right) with 438nm tip diameter.

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 438nm.

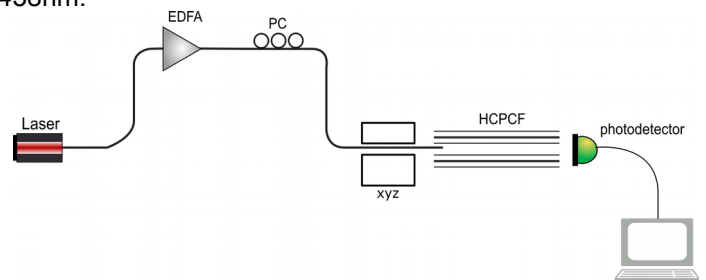


Image 2: Diagram of the measurement setup: laser light is amplified by an EDFA (erbium doped fiber amplifier), passing through a polarization controller and finally reaches the NS. The light then couples into a HCPCF and the transmission is measured by a photodetector.

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 HCPCF.

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 438nm of tip diameter.

Acknowledgement

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¹S Xie, R Pennetta, and P St J Russell. Self-alignment of glass fiber nanospike by optomechanical back-action in hollow-core photonic crystal fiber. *Optica*, 3(3):277-282, 2016.

²Timothy A Birks and Youwei W Li. The shape of fiber tapers. *Journal of Lightwave Technology*, 10(4):432-438, 1992.

³JD Love, WM Henry, WJ Stewart, RJ Black, S Lacroix, and F Gonthier. Tapered single-mode fibres and devices. part 1: Adiabaticity criteria. *IEE Proceedings J (Optoelectronics)*, 138(5):343-354, 1991.