Study and Fabrication of Photonic Nanospikes

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Introduction

Photonic nanospikes (NS) are useful for efficiently launch light in hollow-core photonic crystal fibers(HCPCF)by simply exploring its geometric profile[1].

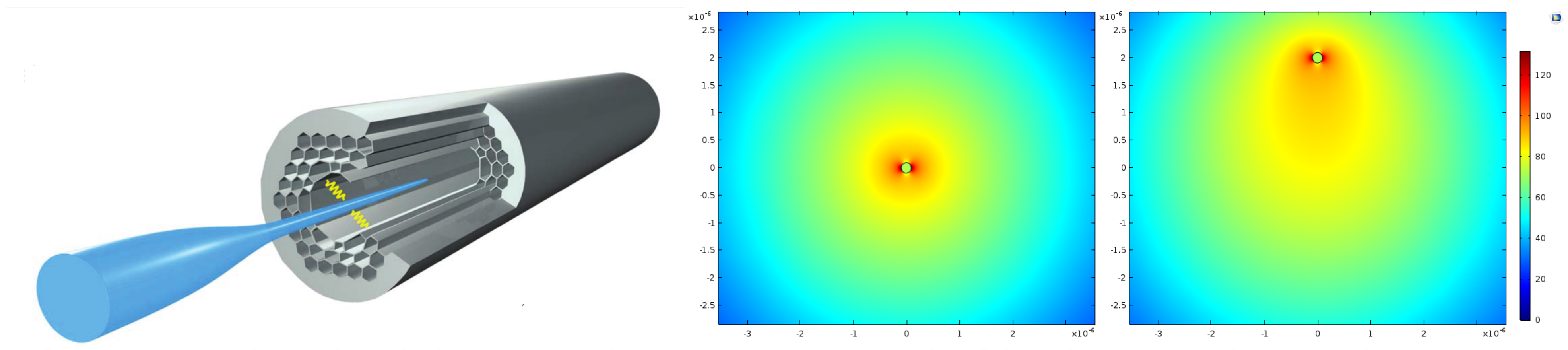
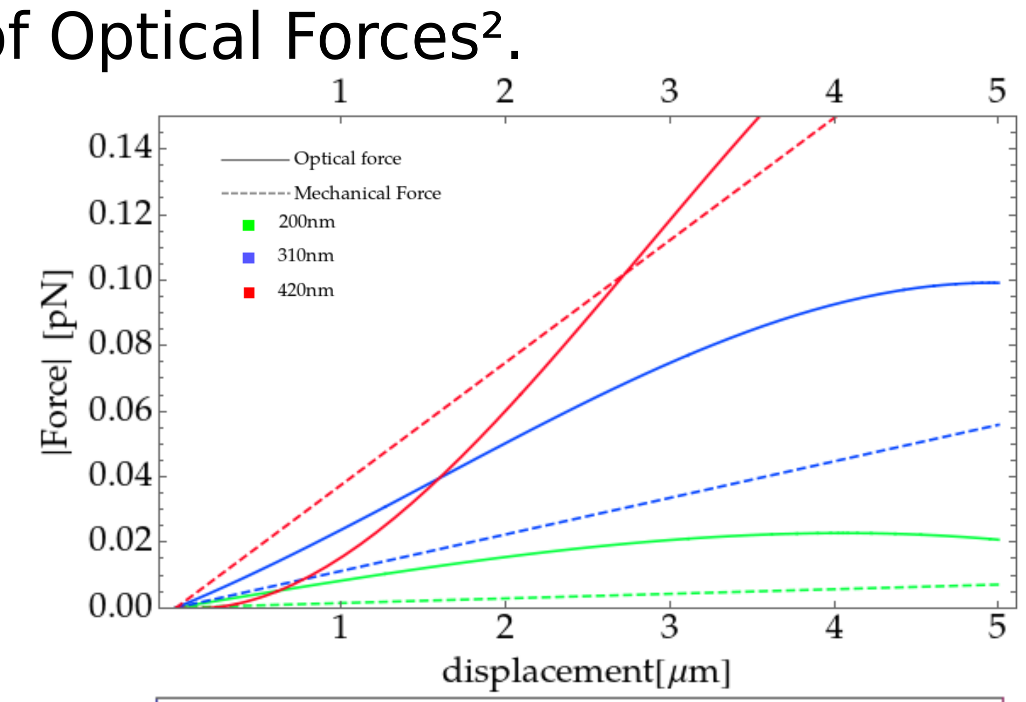


Figure 1: Sketch of the experimental system (left). Simulated Poynting vector distributions of the supermode for a tip of 200nm diameter at displacements of 0μm and 2μm.

A propper design of its tip diameter, within a subwavelength regime, lead to mode-matching, strongly exciting the fundamental mode in the HCPCF. The system exhibits an opto-mechanical response to the displacement of the NS, that is trapped at the center. As a result, the system becomes self-aligned and self-stabilized.

Optical Force

The optical force is calculated according to the Response Theory of Optical Forces[2].



$$F_{opt} = \frac{P\ l}{c}\frac{\partial n_{eff}}{\partial q}$$

$$F_{mec} = \frac{2\pi}{3} Y \frac{r^4}{L^3}\ q$$

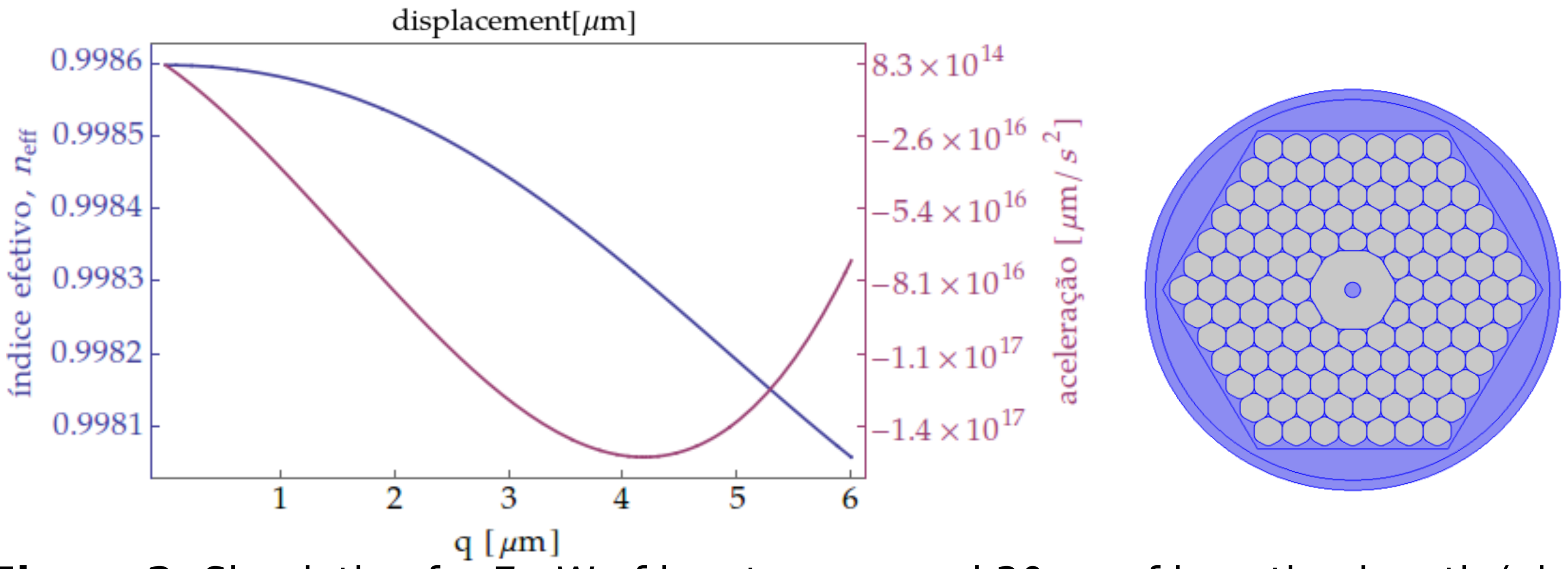


Figure 2: Simulation for 7mW of input power and 30μm of insertion length (above). Simulation for a NS with 310nm tip diameter, all other parameters fixed (below, left). Scheme of the cross section distribution of refractive index for simulations using COMSOl: silica is represented in blue, air in gray (below, right).

Geometric Design - Adiabaticity

$$\left|\frac{dr}{dz}\right| = \Omega \ll \frac{r}{\lambda}(n_{eff,1} - n_{eff,2})\ ^3$$

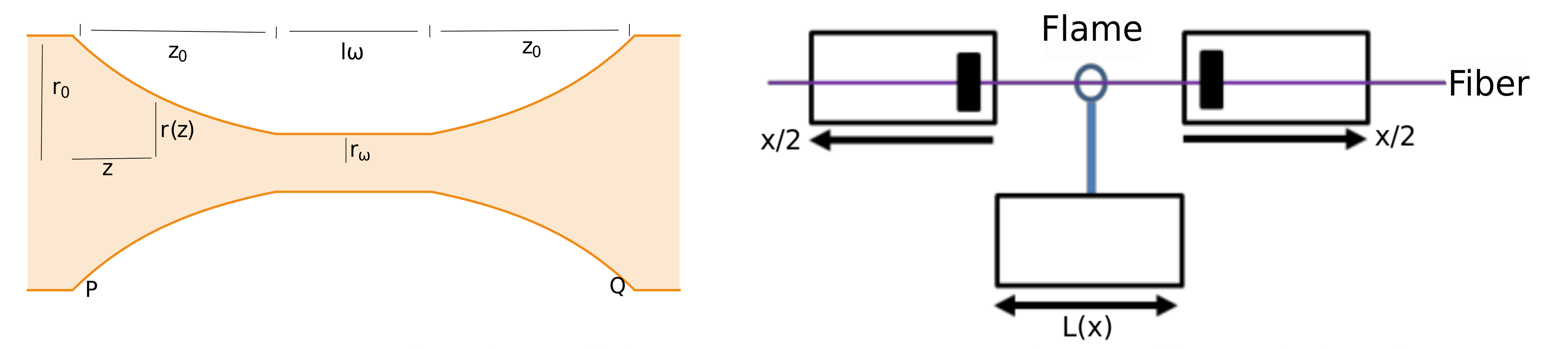


Figure 3: Parameters for describing a taper geometric profile. Fabrication setup scheme.

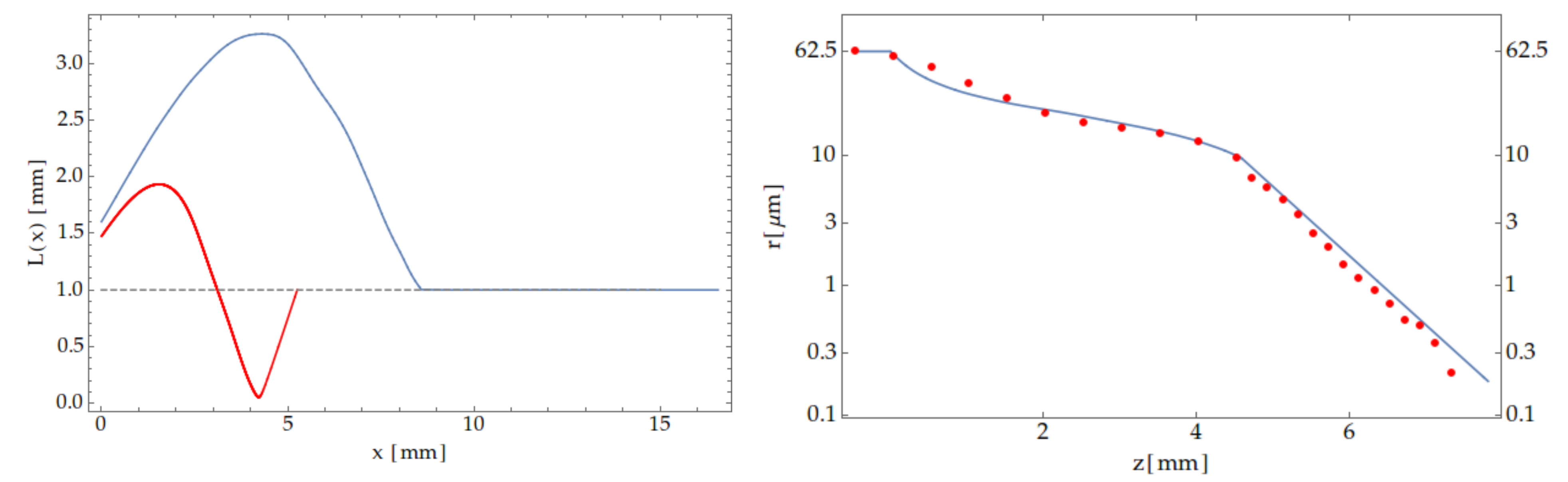


Figure 4: Numerical calculations to obtain a optimized profile design for low loss of the fundamental mode by excitation of higher order modes (left). Short transition regions leads to mechanically robust NS. Predicted profile and SEM measurement data for a fabricated NS.

Measurements

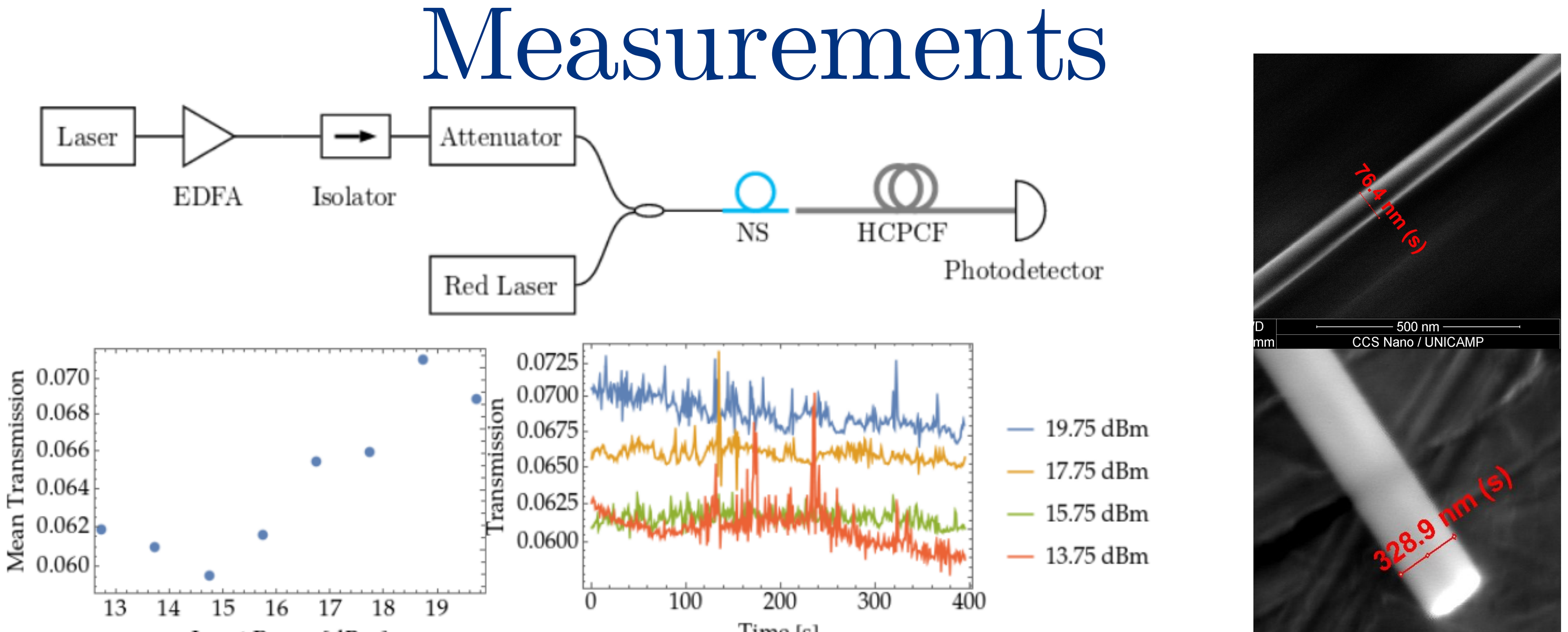


Figure 5: Measurement setup scheme. Transmission measurements. SEM diameter measurements.

Conclusion

An important factor for the feasibility of the experiment is the taper transition profile. Special efforts to obtain a robust and yet adiabatic geometry were performed. The fabrication setup was modified to allow the new parameters.
Numerical calculations shows that tip diameters smaller than 400nm are appropriated for both mode matching and self-alignment at relatively low power.

References:

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[3] JD 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):343354, 1991.

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