Metrology of optical microwires by Brillouin spectroscopy

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We present a novel measurement technique of silica microwire diameter using Brillouin backscattering process. We show that Brillouin spectra of this microwires give rise to acoustical resonances distinctive of their geometry. With the help of an efficient numerical model, the excellent agreement theory/experience allows us to determinate the diameter of the microwire with sensitivity of 10 nm.

Optical microwires are very thin fiberglasses (< 1 μ m) obtained by heating and stretching optical fibers used in telecommunication. Their diameter is mostly measured using difficult methods to implement (microscopy SEM, FIB), not very versatile (harmonic generation [1]), or not sensitive enough (diffraction [2]). Our measurement method is based on the Brillouin backscattering process which allow to excite different type of elastic waves (pressure, shear and surface) covering a large resonance spectrum from 5 GHz to 11 GHz [3]. Each of this resonances verify a phase-matching condition where the acoustical wave vector corresponds to twice the optical wave vector (K = 2Kp). The decreasing of the microwire diameter get decreased the effective refractive index, and by phase-matching, shifted the elastic waves frequencies. The resulting Brillouin spectrum is then different for each diameter and it's from this relation that we developed a numerical model to predict the Brillouin spectrum as a function of the microwire geometry.

Microwires was obtained from a standard fiber SMF-28. This one is fixed on two motorized translation stages stretching the fiber at the same time the flame soft its central part. The shape of the microwire is fully controlled by the trajectories of this two stages. After stretching, the microwire keep linked to the untapered section of SMF-28 by transitions with exponential shape which allow an efficient coupling. The microwires used here get diameters from 600 nm to 3 µm along 4 to 8 cm of length. The total losses in transmission after the pulling is only

around 1.2 dB. The measurement of Brillouin spectra is made by heterodyne detection and electrical spectral analyzer with high resolution [3].

The results show us an excellent agreement between theoretical Brillouin spectrum and experimental spectrum where resonances due to surface and longitudinal elastic waves have a very good superposition (cf. Figure 1). We can distinguish, thanks to the model, resonances due to transition part and waist part of the microwire. The lorentzian shape of resonance peaks show us also a good quality of the fabrication. The diameters determined by theoretical spectra are then confirmed by FIB measurement



Figure 1: Experimental and theoretical Brillouin spectra of a silica microwire with diameter of 800 nm.

with a maximum difference of 5 %. The measurement sensitivity on the diameter can reach 10 nm.

We developed a very efficient technique, passive, and all optical metrology of microwires. It presents a very low error compared to other technique of microscopy. Besides, it is a measurement which can be made in-situ after the stretching without any manipulation of the microwire. This technique is a new tool adapted for the design of microwire.

References

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