Observation of supercontinuum spiral emission in optical fibers

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Research on multimode (MM) optical fibers has attracted an increasing interest in recent years, thanks to their application potential [1]. Studies of nonlinear propagation MM fibers are also interesting for a fundamental viewpoint. Thanks to their unique properties, unexpected and yet to be fully understood wave phenomena have been observed in MM fibers. A remarkable example is the appearance of energetic and multi-octave supercontinuum spectra, extending from the visible to the mid-IR, at sufficiently high pumping intensities [2]. It has been shown that pump pulses with 100 ps temporal durations and peak powers around 200 kW lead to supercontinuum generation in MM fibers with a graded-index (GRIN) core profile [3]. In this work, we reveal that when using femtosecond pump pulses, one has access to a different regime, where the peak power inside the MM fiber may reach and even surpass the critical power P_{cr} for catastrophic self-focusing (this is about 10 MW in fused-silica). When these peak power levels are reached, the propagating light beam undergoes a so-called filamentation phenomenon, leading to the so-called conical emission (CE) [4]. In our experiments, we report for the first time the formation of a supercontinuum spiral emission (SSE), where the spectral components of the output beam are spatially separated in the far-field emitted at the fiber output. We used both a commercial 50/125 GRIN fiber and a 105/125 step-index fiber. Such an unexpected far-field beam shape was obtained by raising the input peak power above the critical threshold P_{cr}. Our pump laser delivered 120 fs pulses at 1030 nm with up to 25 MW peak power. The repetition rate was set to 2 kHz, and the beam was focused by a 19 mm lens, producing an 8 μm beam waist at the fiber input facet. We show here results with a 2 cm long multimode standard GRIN and step-index fiber, relative index difference $\Delta = 0.0103$ (cladding refractive index is 1.457), and chromatic dispersion $\beta_2 = -22$ ps^2/km.

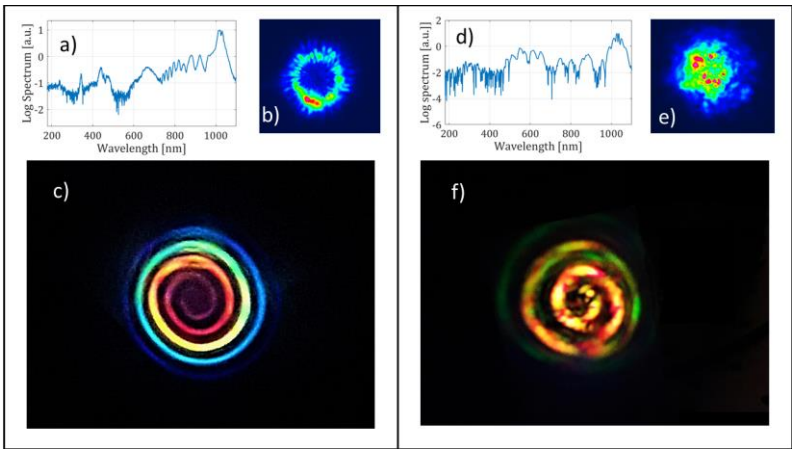

Fig. 1 Experimental results obtained in a 50/125 GRIN fiber (left panel) and Step-index fiber (right panel); a) Output spectrum at 25 MW input peak power (logarithmic scale); b) near field; c) far field.

In Figs.1.a, the output spectrum shows an ultrabroadband distribution, ranging from the UV up to the pump wavelength. The near-field profile at the fiber output shows that the supercontinuum only propagates inside the cladding (see Figs. 1.b). Finally, the far-field SSE is shown in Figs. 1.c. In Fig1 d)-f) we show how the spectrum, the near- and far-field profiles change when the input coupling condition is slightly changed. The spiral-shaped emission is maintained. However, the supercontinuum distribution no longer shows a spatially separated spectral distribution. Moreover, the near-field manifests the typical multimodal speckled profile. A theoretical model able to describe SSE generation is being developed.

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