Polarization analysis of a supercontinuum generated in a germania-doped photonic crystal fiber

N. Couture[1], R. Ostic[1], P. H. Reddy[2,3], S. Das[3], A. Dhar[3], M. C. Paul[3], A. K. Kar[4] and J.-M. Ménard[1]

[1]Department of Physics, University of Ottawa, Ottawa, ON K1N 6N5, Canada

[2]Academy of Scientific and Innovative Research (AcSIR), CSIR-CGCRI Campus, Kolkata-700032, India

[3]Fiber Optics and Photonics Division, CSIR-Central Glass and Ceramic Research Institute, Kolkata-700032, India

[4]Institute of Photonics and Quantum Sciences, Heriot-Watt University, Riccarton Campus, Edinburgh EH14 4AS, UK

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Motivation

- Supercontinuum (SC) sources are important for photonic device testing, optical coherence tomography, and optical communication [1].
- Nonlinear optical propagation in photonic crystal fibers (PCFs) can lead to a broad and flat output spectrum, but little is known about their polarization properties.
- We demonstrate a free-space polarization-sensitive spectroscopy system covering a 3-octave bandwidth capable of measuring the spectrum of the light propagating in each of a fiber's principal axes.
- We characterize the input polarization and power dependences of a SC generated in a GeO_2-doped PCF.

Fiber Characterization

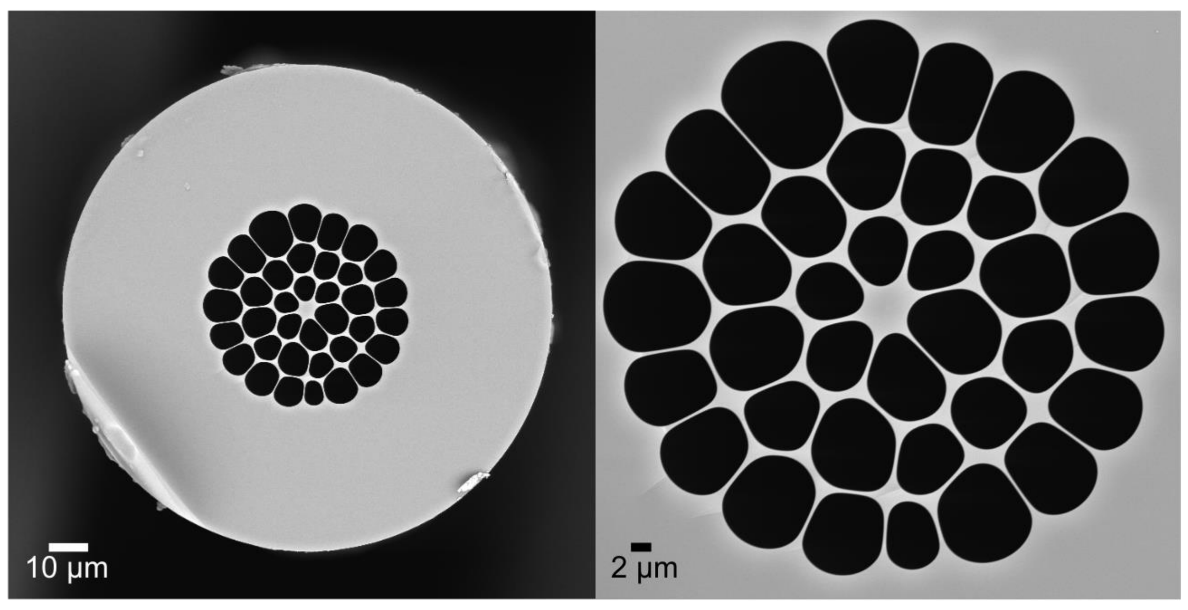

Fig. 1: Scanning electron microscope (SEM) image of the PCF

- The core of the PCF has a small asymmetry, with an average diameter of 4.7 µm, and displays low birefringence.
- GeO_2-doping concentration of 50% in the center of the preform is measured with an electron probe micro-analyzer.
- Doping provides a high refractive index contrast Δn ~ 0.045 reducing modal overlap with the air-SiO_2 interface, which reduces propagation loss and enhances nonlinear effects.

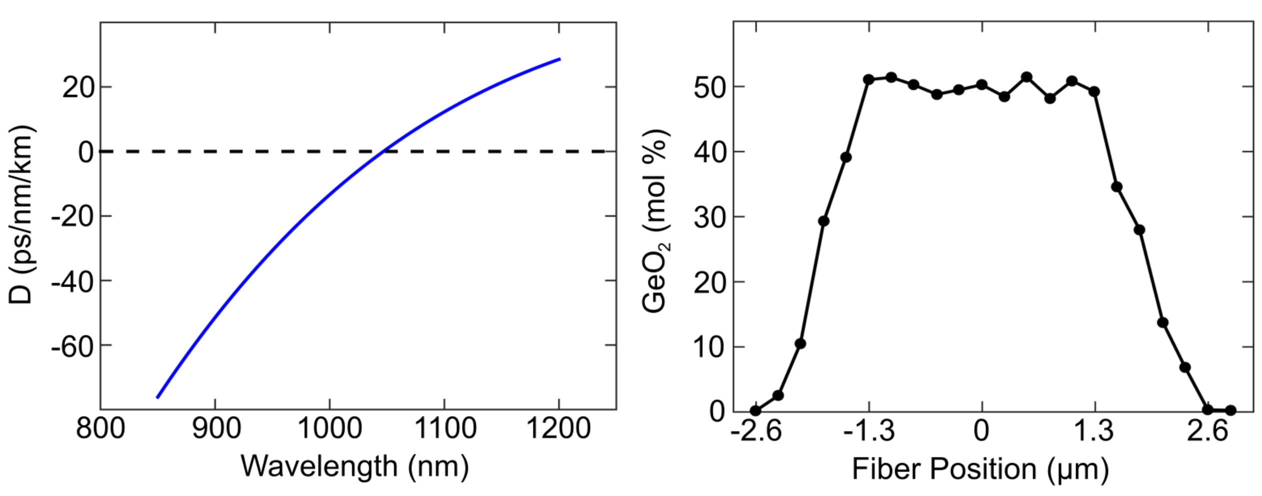

Fig. 2: Dispersion profile and germania concentration of the fiber

- Dispersion profile is measured by placing the fiber in a Mach-Zehnder interferometer.
- The zero-dispersion wavelength is 1047 nm.

Experiment

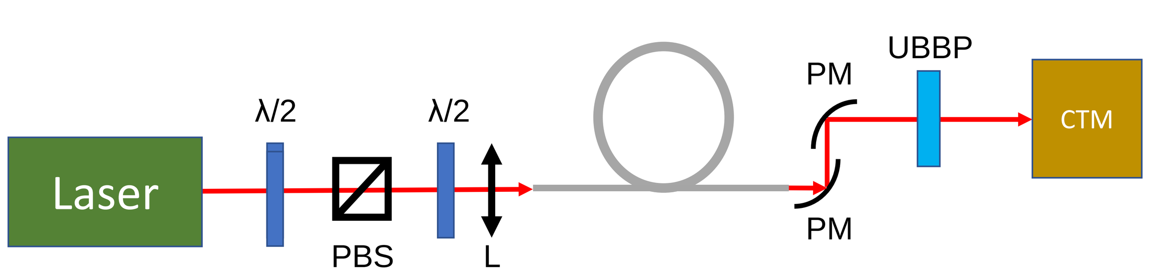

Fig. 3: Schematic of the experimental setup

- The laser delivers 180 fs pulses at λ = 1030 nm.
- Spectrum is measured with a Czerny-Turner Monochromator (CTM) employing 3 gratings and 3 photodetectors.
- Pulses are launched into a 1.9 meter-long fiber. The principal axes at the output facet of the PCF are aligned to the TE and TM modes of the gratings in the CTM.
- Ultrabroadband polarizer (UBBP) selects the polarization state of the beam sent into the spectrometer.

Supercontinuum Generation

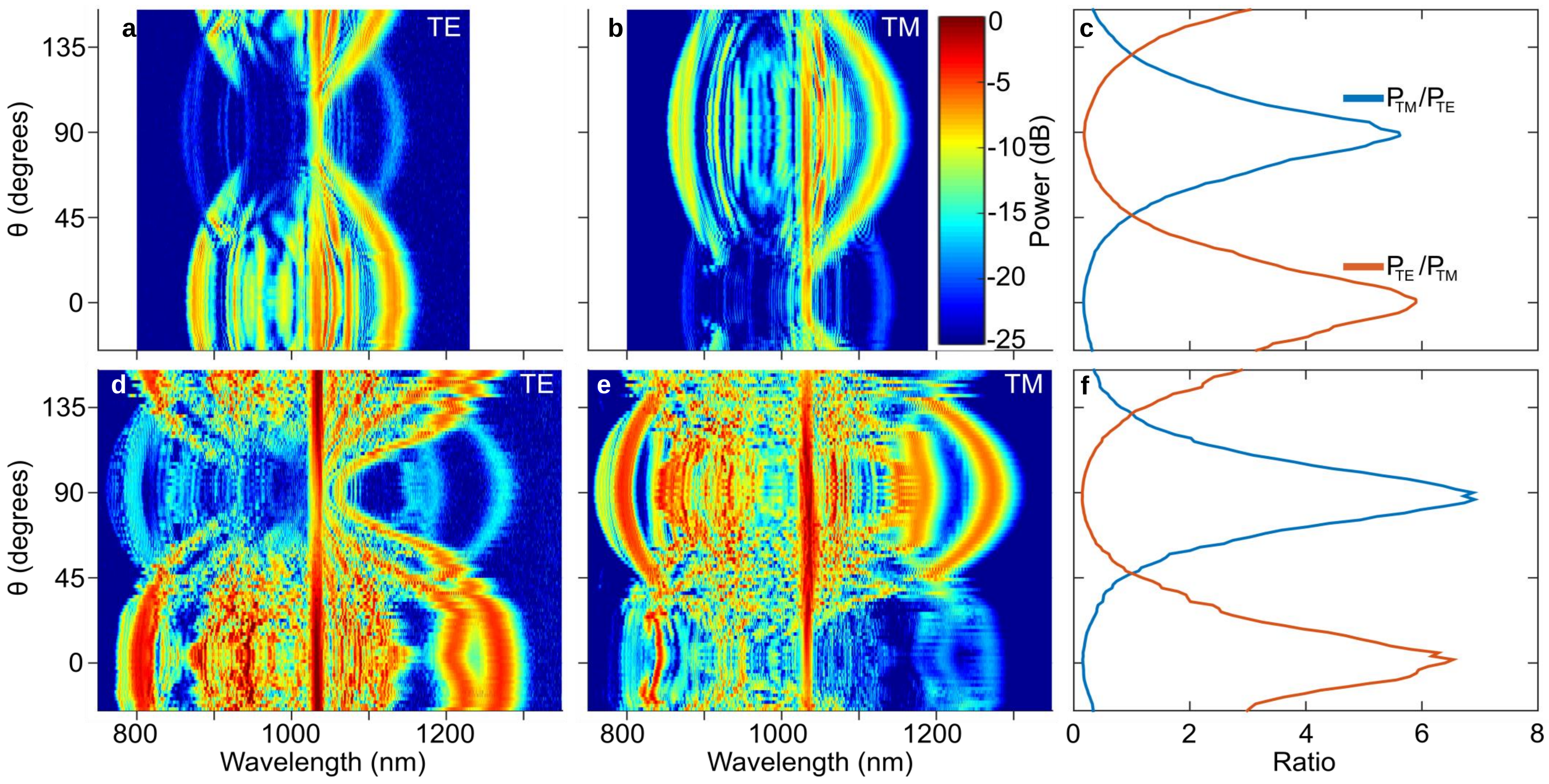

Fig. 4: Evolution of the SC spectrum at the output of the fiber as we rotate the input linear polarization at a fixed pulse energy of 0.3 nJ (a, b) and 1.1 nJ (d, e). c,f) Ratios of the TE and TM polarization components of the integrated spectra.

- The elevated power ratios at $\theta = 0°$ and 90° map out the location of each principal axis and indicate that light injected at these angles is most polarized at the output of the PCF.
- At $\theta = 45°$ and 135°, the ratio is 1, meaning that there is an equal optical power distributed in both polarization components aligned along a principal axes.
- The spectral shadows at $\theta = 90°$ in Fig. 4 (a) and (d) and at $\theta = 0°$ in Fig. 4 (b) and (e) show that light scatters into orthogonal fiber axes at the output of the fiber; likely due to the fiber clamping mechanisms.

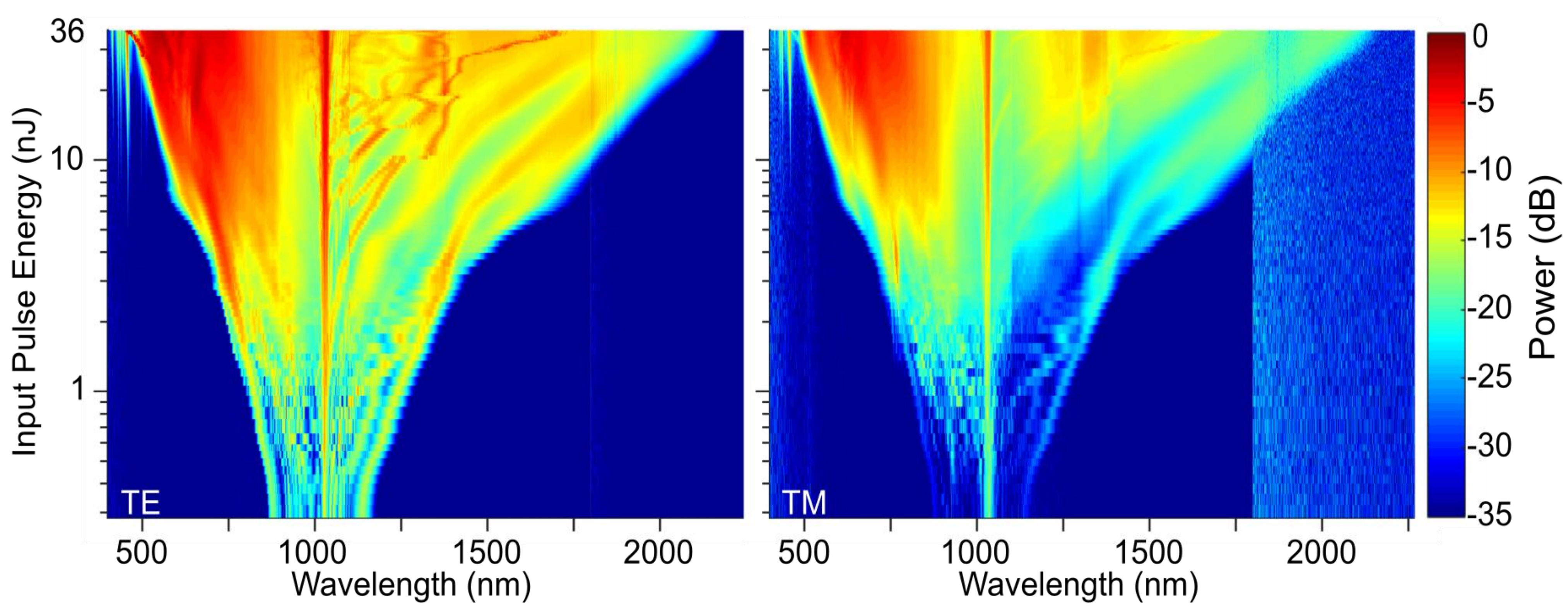

Fig. 5: Evolution of the spectrum (separated in its TE and TM components) as we increase the pulse energy launched in the fiber from 0.3 to 36 nJ. The input linear polarization is set along one of the principal axes of the fiber ($\theta = 0°$ in the Fig. 4)

- Red-shifting Raman solitons and their corresponding dispersive waves extend the output SC from 450 to 2150 nm when launching linearly polarized light along a principal axis.
- In the TM-polarized SC, the lack of defined solitonic structure and large spectral weight at short wavelengths indicate that Rayleigh scattering may intrinsically be the main depolarization mechanism [2].

Conclusion

- We demonstrate the polarization sensitivity of our spectrometer, successfully separating orthogonal polarization components aligned to the PCF's principal axes.
- Our results reveal wavelength and pulse energy dependences in depolarization mechanisms, a result that is not possible with conventional measurement techniques such as an Optical Spectrum Analyzer (OSA).
- Our spectrometer holds the potential to become the new standard in characterizing fiber-based SC sources as it unveils the polarization properties of each spectral component.

References

[1] Jiao *et al.*, "Mid-infrared flattened supercontinuum generation in all-normal dispersion tellurium chalcogenide fiber," Opt. Express **27**, 2036–2043 (2019)

[2] N. Couture *et al.*, "Polarization-resolved supercontinuum generated in a germania-doped photonic crystal fiber," *in preparation* (2020)