Polarization-dependent relative intensity noise of fiber supercontinuum sources

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Highly coherent and low noise supercontinuum (SC) sources based on nonlinear spectral broadening of femtosecond pulses in all-normal dispersion (ANDi) fibers are attractive for many applications in ultrafast photonics, such as nonlinear bio-photonic imaging, ultrafast spectroscopy, coherent X-ray generation, and low-noise ultrafast fiber laser development, amongst others [1]. The noise properties of the SC source are of particular importance as fluctuations translate to intensity noise, pulse duration noise, or timing jitter, affecting sensitivity, resolution, or synchronisation of ultrafast experiments. While ANDi SC exhibit superior noise properties compared to their conventional counterparts pumped in the anomalous dispersion regime, recent theoretical studies suggest that polarization modulation instability (PMI) can severely degrade their stability [2].

Here we present, for the first time, detailed experimental polarization-dependent relative intensity noise (RIN) measurements of ANDi SC sources based on both polarization-maintaining (PM) and non-PM fibers, and compare them to a conventional SC source (Fig. 1). All fibers were pumped with an ultrafast Er:fiber laser (80 fs, 40 MHz, 0.05% RIN), generating SC with comparable spectral bandwidths in the range 1.2 – 2.2 µm. A rotating half-wave plate in front of the fiber and a synchronized analyzer at the fiber exit controlled the plane of pump pulse and detection polarization with respect the fiber's principal axes. Integrated RIN values from 0-18 MHz were measured using a photodiode and electronic spectrum analyzer with an angular resolution of approximately 0.2°.

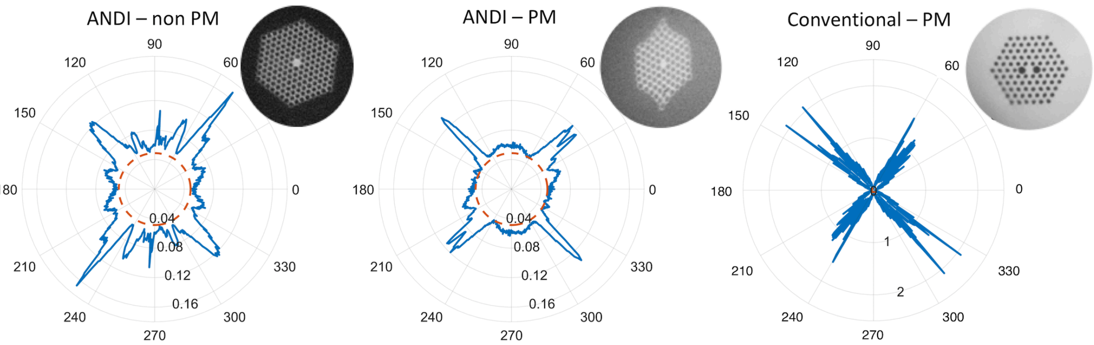

Fig. 1: Polarization-dependent RIN measurements of SC generated in ANDI PM and non-PM fiber as well as in a commercial conventional nonlinear PM fiber pumped in the anomalous dispersion regime (NKT PM-1550-01). The polar plot shows the polarization angle of the pump pulses with respect to the principal fiber axes, the RIN values are integrated from 0-18 MHz and given in percent. The red-dotted line shows the RIN of the pump laser.

Figure 1 presents polarization-dependent RIN measurements for each fiber sample. While the SC generated in the non-PM ANDi fiber shows complex, polarization dependent RIN features that are sensitive to environmental conditions, amplifying the pump laser noise by a factor of up to 3, the PM design completely suppresses noise amplification by PMI around the fiber's principal axes with high environmental stability. In this case, the RIN of the SC shows only very weak dependence on pump pulse polarization and is virtually identical to the RIN of the pump laser, except for sharp peaks at 45° to the principal axis where the noise of the pump laser is amplified by a factor of 2. In contrast, the RIN of the conventional SC source rises sharply for off-axis polarization reaching maximum RIN values of 2 %, which corresponds to a noise amplification factor of about 40.

Our results demonstrate that the ANDi PM fiber design can effectively suppress nonlinear noise amplification by PMI during SC generation. In addition, ANDi-PM SC sources prove to be robust against input polarization fluctuations, while the noise of conventional SC sources, even when based on PM-fiber, rises sharply for slight misalignment between pump laser polarization and fiber axes. In combination with the previously demonstrated minimization of both quantum and technical noise amplification in ANDi fibers [3,4], our results underline the substantial potential of the ANDi fiber design for applications that require ultra-low noise, high quality SC sources.

References

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