SUPERCONTINUUM GENERATION WITH RUGGED FEMTOSECOND FIBER LASERS

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Objectives & Expected results:

- *Investigation of SCG with rugged mode-locked femtosecond fiber lasers using Yb-fiber lasers (1.03 μm) or Er-fiber lasers (1.55 μm).*
- *SCG from 0.7-3.5 μm in soft glass fibers (tellurite)*
- *High-power vis-near-IR-mid-IR SCG (0.5-3.5 μm)*

Current Activities:

- *Ultra-low noise SCG using flat-near zero dispersion pure silica fiber along with relative intensity noise (RIN) measurement.*
- *Numerical modeling corroborating the measured spectra and noise*
- *NIR set up to measure dispersion of the medium with input polarization control*
- *Investigation of Directional SCG*

Results & Discussion:

a) SCG in Flat-normal dispersion pure silica fiber with 1.55 μm fs pump:

- *In ANDi fibers, generated SC preferentially broadens towards the wavelength region with low dispersion*
- *Parametric Raman gain length, L_R^* is inverse of g_s^*:*

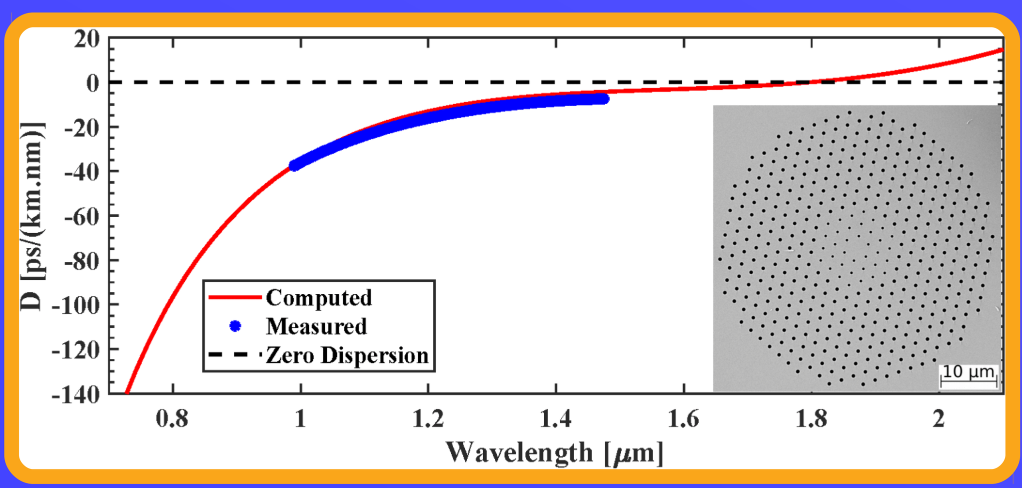


Fig 1: D of the fiber

$$g_s^* = 2\gamma\, Re\left(\sqrt{K(2q-K)}\right) \quad where, \quad K = -\frac{\beta_2\Omega_R^2}{2\gamma P_0}, \quad q = (1-f_R) + f_R\tilde{\chi}_R^{(3)}(-\Omega_R)$$

- *Low β_2 leads to a large L_R^* ⇒ suitable to generate coherent SC even when pumped with a several hundreds of fs pulse*
- *Dispersion (D) of the fiber is flat and close to zero around 1.55 μm. Experimentally measured D is plotted in Fig 1.*

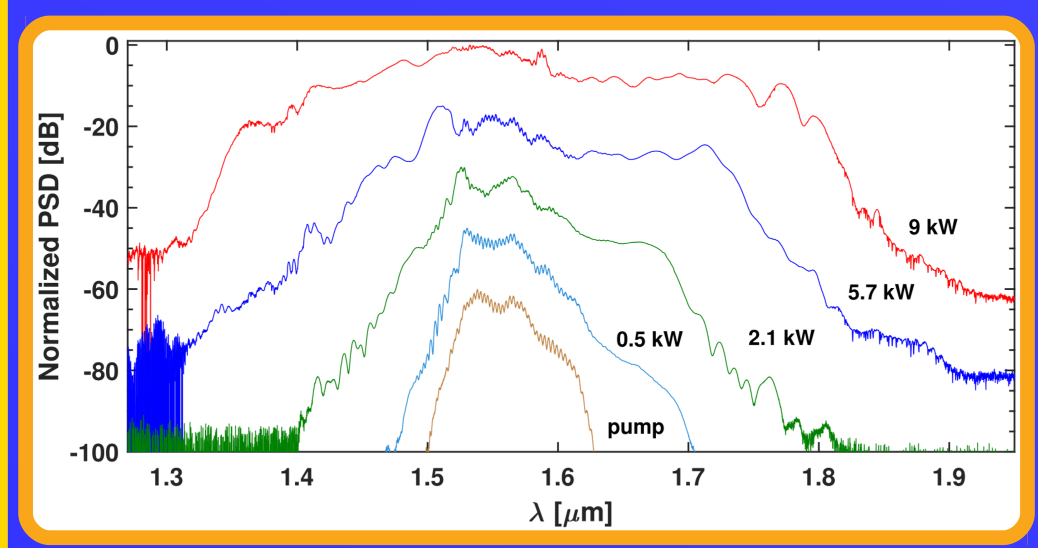


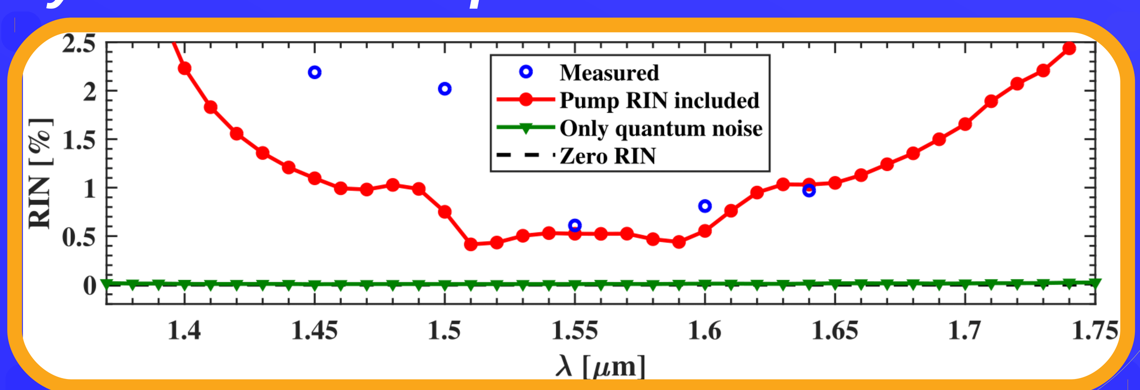
Fig 2: SC

- *A 125 fs pulse at 1.55 μm was launched, and the spectra obtained are plotted in Fig 2.*
- *Low noise of the SCG was characterized by RIN measurements*

Additional experimental setups built:

- *Spectral interferometry based NIR dispersion measurement setup*
- *RIN measurements:*

Fig 3: Measured RIN of the normal dispersion fiber based SC



b) Directional SCG:

- *In this scheme the pump is in the NDR but close to a ZDW*
- *The fs pump is in NDR II and the spectrum initially broadens from SPM.*
- *A part of the pulse then leaks into ADR I and develops into a soliton*
- *Soliton initially blue shifts from XPM from the pulse in NDR II and later redshifts from Raman induced self frequency shift*

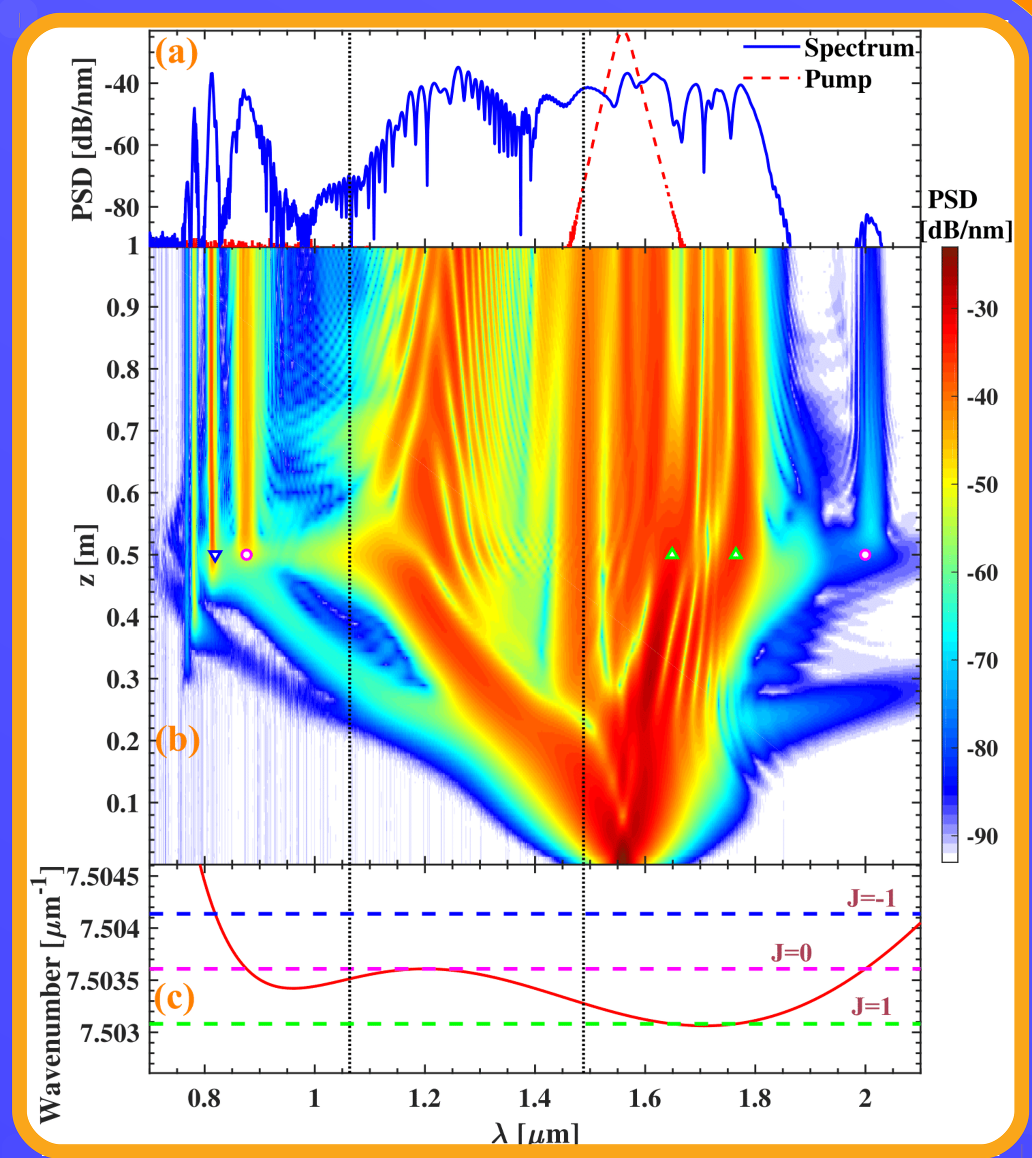


Fig 4: Directional SC, P_0= 9 kW, T_{FWHM}= 125 fs

- *Degenerate and non-degenerate FWM between the solitons and the pulse in NDR II leads to DWs, given by:*

$$\beta_{lin}(\omega_d) = J[\beta_{lin}(\omega_p) - \beta_{sol}(\omega_p)] + \beta_{sol}(\omega_d); \quad for \quad J = -1,0,1$$

- *Octave spanning SCG'ed (Fig 4) directionally across the ADR I*
- *Provides a flexible pumping scheme to use a commercially available fiber lasers i.e. the pump need not always be in the ADR*

Future plan:

- *Experimental investigation of SCG in Soft glass fibers using 1.55 μm fs pump*
- *Investigation of SCG in Telluride fiber from ESR 6*
- *Noise measurement of the generated SCG*

Dissemination:

- *Simon Christensen, Shreesha Rao. D. S, Ole Bang, and Morten Bache, "Directional Supercontinuum Generation in Waveguides and Fibers ", in Review, J. Opt. Soc. Am. B.*
- *Shreesha Rao. D. S, Rasmus D. Engelsholm, Ivan B. Gonzalo, Binbin Zhou, Patrick Bowen, Peter M. Moselund, Ole Bang, and Morten Bache, "Ultra-low Noise Supercontinuum Generation with a Flat-Near-zero Normal Dispersion Fiber ", Manuscript in preparation to be submitted to Optics letters.*
- *Shreesha Rao. D. S, Rasmus D. Engelsholm, Ivan B. Gonzalo, Binbin Zhou, Patrick Bowen, Peter M. Moselund, Morten Bache, and Ole Bang, "Ultra-low Noise Supercontinuum Generation with Flat-near Zero All Normal Dispersion Pure Silica Fiber at GHz Repetition Rate". OSA Advanced Photonics Congress,2 – 05 July 2018 ETH Zürich, Zürich, Switzerland, (Oral presentation)*
- *Shreesha Rao. D. S, et. al. "Ultra-low Noise Supercontinuum Generation with Flat-near Zero All Normal Dispersion Pure Silica Fiber at GHz Repetition Rate". Symposium on Future Prospects for Photonics on Mid-Infrared Light Sources and Applications, Tampere, Finland, on December 13-14, 2017, (Poster presentation)*
- *Shreesha Rao. D. S, et. al. "Ultra-low Noise Supercontinuum Generation with Flat-near Zero All Normal Dispersion Pure Silica Fiber at GHz Repetition Rate". International OSA Network of Students (IONS) Scandinavia conferences, Lyngby, Technical University of Denmark, Denmark, on 06-08 June 2018, (Poster presentation)*

ECTS Credits:

- *Course: Novel Optical Fibers in Life Science (5 ECTS)*
- *Course: Pitching High-Tech Projects (1 ECTS)*
- *IONS Scandinavia: PhD-course at DTU Fotonik (2.5 ECTS)*
- *SC broadband light sources for UV and IR applications, France (1 ECTS)*
- *Future Prospects for Photonics on Mid-IR Light Sources, Finland (2 ECTS)*
- *Workshop on PCF Tech. For Ultrafast Optics Appl., Poland (1 ECTS)*

Planned:

- *Course: Patent course (Jan 2019, 3 ECTS)*
- *Int. Summer school, Frontiers in Optical Tech., Finland (2019, 3 ECTS)*
- *SUPUVIR Microscopy Workshop in Cambridge (Nov 18, 2 ECTS)*
- *PhD specialized course: Ultrafast Optics (10 ECTS)*

Secondments:

(1) To build a high power fs laser at NKT Phtonics, supervisor; Patrick Bowen (Mar-Apr '19)

(2) X-FROG measurements of SC at Femto-st, France; supervisors:Thibaut Sylvestre and John Dudley (~1 month, TBD)

(3) Pulse to pulse noise measurements of SC, University of Bern, Switzerland; supervisor: Alexander Heidt (~2 weeks, TBD)

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SUPUVIR
SUPercontinuum broadband light sources covering UV to IR applications