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Vasilii Voropaev, Shangran Xie, Aleksandr Donodin, Dmitrii Vlasov, Daniil Batov, et al.. Octave-Spanning Supercontinuum Generated in As₂S₃-Silica Waveguides Pumped by Tm-doped All-fibre MOPA. Conference on Lasers and Electro-Optics Europe / European Quantum Electronics Conference (CLEO/Europe-EQEC), Jun 2021, Munich, Germany. 10.1109/CLEO/Europe-EQEC52157.2021.9542421 . hal-03597025

HAL Id: hal-03597025

<https://hal.science/hal-03597025v1>

Submitted on 3 Sep 2024

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Octave-Spanning Supercontinuum Generated in As₂S₃-Silica Waveguides Pumped by Tm-doped All-fibre MOPA

Vasilii Voropaev¹, Shangran Xie², Aleksandr Donodin³, Dmitrii Vlasov¹, Daniil Batov¹, Mikhail Tarabrin^{1,4}, Johann Troles⁵, Vladimir Lazarev¹

1. Science and Education Center for Photonics and IR-Technology, Bauman Moscow State Technical University, 105005, Moscow, Russia

2. Max Planck Institute for the Science of Light, 91058, Erlangen, Germany

3. Aston Institute of Photonic Technologies, Aston University, B4 7ET, Birmingham, United Kingdom

4. Frequency standards Laboratory, P. N. Lebedev Physical Institute of the Russian Academy of Sciences, 119991, Moscow, Russia

5. Institut des sciences chimiques de Rennes, Université de Rennes 1, 35042, Rennes, France

Fiber-based supercontinuum sources in the mid-IR wavelength range are highly desirable for many applications [1-3]. Here we report the generation of octave-spanning supercontinua in As₂S₃-silica hybrid waveguides pumped by a thulium-doped all-fiber master-oscillator-power-amplifier (MOPA). The narrow As₂S₃ core of the step-index waveguide has an extremely high nonlinearity, and by balancing its anomalous geometrical dispersion against the normal dispersion of the glass, the zero dispersion wavelength of the guided mode can be shifted towards the pump wavelength by suitable design. The “nanospikes” at both ends of the hybrid waveguide (see Fig. 1a) are used to boost the launch efficiency into the fundamental core mode [3,4]. A thulium-doped all-fiber MOPA centred at 1.9 μm [5,6] was used as pump source. It emits pulses with a duration of 78 fs and a maximum peak power of 200 kW at a repetition rate of 23.8 MHz. Dual nanospike waveguides with core diameters $d = 1.7 \mu\text{m}$ and $1.2 \mu\text{m}$ were tested in the experiment. The length of both waveguides was 3 mm. Fig. 1b plots the calculated dispersion parameter of the two waveguides. For $d = 1.7 \mu\text{m}$ the pump lies within $\sim 50 \text{ nm}$ of a zero dispersion wavelength, in which case for a launched energy of $\sim 32 \text{ pJ}$ the measured spectrum at the output extends from $1.1 \mu\text{m}$ to $2.5 \mu\text{m}$ at the -10 dB level. The total output average power was measured as $\sim 1.2 \text{ mW}$. When $d = 1.2 \mu\text{m}$, the pump wavelength lies in between two zero dispersion wavelengths, and for 23 pJ launched energy the spectrum extends from $1.7 \mu\text{m}$ to $2.3 \mu\text{m}$, while a weak dispersive wave appears at 963 nm . In both cases the third harmonic components are visible at 630 nm (inset of Fig. 1c), which fall within the bandgap of the As₂S₃ material, limiting further increase of the pump energy. Numerically simulated spectra (black-dotted curves) calculated for the experimental pulse energy agree well with the measurements.

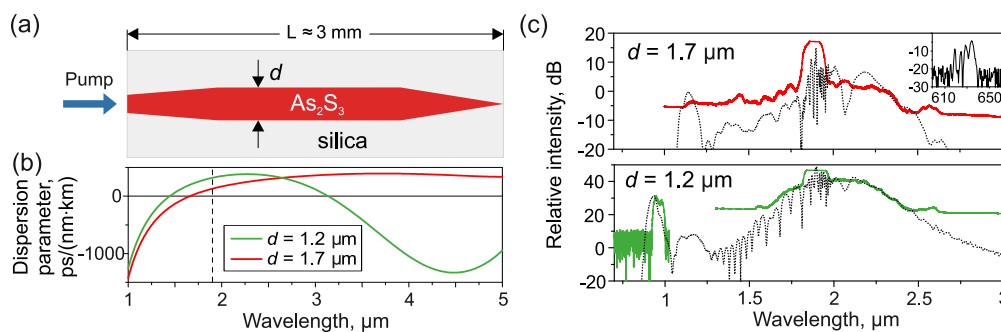


Fig. 1 (a) Sketch of a As₂S₃-silica hybrid nanospike waveguide. (b) Calculated dispersion parameter of waveguides with $d = 1.7 \mu\text{m}$ (red) and $1.2 \mu\text{m}$ (green). (c) Measured supercontinuum spectra at the output endface of waveguide when $d = 1.7 \mu\text{m}$ (top) and $d = 1.2 \mu\text{m}$ (bottom), together with the simulated spectra (black-dotted lines). The inset shows the observed third harmonic signal at around 630 nm wavelength.

In conclusion, octave-spanning supercontinua can be generated in As₂S₃-silica dual nanospike waveguides pumped by a fs Tm-doped fiber laser. The results may lead to long-term-stable, spectrally coherent, all-fiber supercontinuum sources in the mid-IR.

References

- [1] A. Donodin et al., “Femtosecond thulium-doped fiber-ring laser for mid-IR spectroscopic breath analysis,” Saratov Fall Meeting 2018: Laser Physics, Photonic Technologies, and Molecular Modeling. International Society for Optics and Photonics **11066**, 1106603 (2019).
- [2] V. Voropaev et al., “Generation of multi-solitons and noise-like pulses in a high-powered thulium-doped all-fiber ring oscillator,” *Sci. Rep.* **9**, 1-11 (2019).
- [3] S. Xie et al., “As₂S₃-silica double-nanospike waveguide for mid-infrared supercontinuum generation,” *Opt. Lett.* **39**, 5216-5219 (2014).
- [4] A. Donodin et al., “Supercontinuum Generation in a As₂S₃-Silica Nanospike Waveguide Pumped by Tm-Doped Fiber Laser,” *CLEO Europe*, 1-1 (2019).
- [5] V. S. Voropaev et al., “Ultrashort Pulse Amplification and Compression at $1.9 \mu\text{m}$ Using Normal Dispersion Thulium-Doped Germanosilicate Fiber,” *Laser Science*, Optical Society of America, LW7G-2 (2020).
- [6] A. Donodin et al., “Numerical model of hybrid mode-locked Tm-doped all-fibre laser,” *Sci. Rep.* **10**, 1-9 (2020).