Role of the Raman gain in the noise dynamics of all-normal dispersion silica fiber supercontinuum generation

We theoretically and numerically study the influence of the Raman gain profile on the noise dynamics of the supercontinuum (SC) generation in a standard all-normal dispersion silica fiber using the scalar generalized nonlinear Schrödinger equation. In particular, we investigate the effect of the different secondary resonance gain peaks on the evolution of the SC coherence by comparing the coherence obtained when using the measured Raman gain of silica with that obtained using different analytical approximations. We demonstrate that the strongest secondary peak at 14.8 THz has a significant influence in that it leads to an early development of a decoherence band on the long wavelength side of the SC. In contrast, the decoherence is strongly dominated by the short wavelength side below the pump for all analytical models not taking this 14.8 THz gain peak into account. We demonstrate that this is due to the 14.8 THz peak being spectrally much narrower than the other gain peaks.
Lipids are highly coveted for the interrogation of fatal chronic diseases. We propose cost-efficient high pulse energy supercontinuum source, using telecom range diode laser and standard optical fiber for photoacoustic detection and
Polarization noise places severe constraints on coherence of all-normal dispersion femtosecond supercontinuum generation

Supercontinuum (SC) generated with all-normal dispersion (ANDi) fibers has been of special interest in recent years due to its potentially superior coherence properties when compared to anomalous dispersion-pumped SC. However, care must be taken in the design of such sources since too long pump pulses and fiber length has been demonstrated to degrade the coherence. To assess the noise performance of ANDi fiber SC generation numerically, a scalar single-polarization model has so far been used, thereby excluding important sources of noise, such as polarization modulational instability (PMI). In this work we numerically study the influence of pump power, pulse length and fiber length on coherence and relative intensity noise (RIN), taking into account both polarization components in a standard ANDi fiber for SC generation pumped at 1064 nm. We demonstrate that the PMI introduces a power dependence not found in a scalar model, which means that even with short ~120 fs pump pulses the coherence of ANDi SC can be degraded at reasonable power levels above ~40 kW. We further demonstrate how the PMI significantly decreases the pump pulse length and fiber length at which the coherence of the ANDi SC is degraded. The numerical predictions are confirmed by RIN measurements of fs-pumped ANDi fiber SC.
Supercontinuum applications in high resolution non invasive optical imaging
Progress will be presented in adapting supercontinuum sources to a variety of applications with emphasis on signal processing procedures. These are customised to alleviate noise and take full advantage of the large bandwidth and large power spectral density of modern supercontinuum sources.

General information
State: Published
Organisations: Department of Photonics Engineering, Fiber Sensors and Supercontinuum Generation, University of Kent, University of Copenhagen, NKT Group
Number of pages: 2
Pages: 1-2
Publication date: 2018

Host publication information
Title of host publication: Proceedings of 2018 Conference on Lasers and Electro-Optics (CLEO)
Publisher: Optical Society of America OSA
ISBN (Print): 9781943580422
Keywords: Optical coherence tomography, Bandwidth, Image resolution, Optimized production technology, Fiber lasers, Laser noise, Semiconductor lasers
DOIs: 10.1364/CLEO_AT.2018.AW3S.1

Bibliographical note
From the session: A&T Topical Review on Advances in Supercontinuum Technologies II: New Application Areas for Supercontinuum light sources (AW3S)
Source: FindIt
Source-ID: 2438376989
Ultra-low noise supercontinuum source for ultra-high resolution optical coherence tomography at 1300 nm

Supercontinuum (SC) sources are of great interest for many applications due to their ultra-broad optical bandwidth, good beam quality and high power spectral density [1]. In particular, the high average power over large bandwidths makes SC light sources excellent candidates for ultra-high resolution optical coherence tomography (UHR-OCT) [2-5]. However, conventional SC sources suffer from high pulse-to-pulse intensity fluctuations as a result of the noise-sensitive nonlinear effects involved in the SC generation process [6-9]. This intensity noise from the SC source can limit the performance of OCT, resulting in a reduced signal-to-noise ratio (SNR) [10-12]. Much work has been done to reduce the noise of the SC sources for instance with fiber tapers [7,8] or increasing the repetition rate of the pump laser for averaging in the spectrometer [10,12]. An alternative approach is to use all-normal dispersion (ANDi) fibers [13,14] to generate SC light from well-known coherent nonlinear processes [15-17]. In fact, reduction of SC noise using ANDi fibers compared to anomalous dispersion SC pumped by sub-picosecond pulses has been recently demonstrated [18], but a cladding mode was used to stabilize the ANDi SC. In this work, we characterize the noise performance of a femtosecond pumped ANDi based SC and a commercial SC source in an UHR-OCT system at 1300 nm. We show that the ANDi based SC presents exceptional noise properties compared to a commercial source. An improvement of ~5 dB in SNR is measured in the UHR-OCT system, and the noise behavior resembles that of a superluminescent diode. This preliminary study is a step forward towards development of an ultra-low noise SC source at 1300 nm for ultra-high resolution OCT.

General information
State: Published
Organisations: Department of Photonics Engineering, Fiber Sensors and Supercontinuum Generation, NKT Group, University of Kent
Contributors: Bravo Gonzalo, I., Maria, M., Engelsholm, R. D., Feuchter, T., Leick, L., Moselund, P. M., Podoleanu, A., Bang, O.
Number of pages: 7
Publication date: 2018

Host publication information
Title of host publication: Proceedings of SPIE
Publisher: SPIE - International Society for Optical Engineering
Article number: 104860N
Keywords: Optical Coherence Tomography, Supercontinuum, All-Normal Dispersion Fibers, Noise
Electronic versions:
BIOS_Ultra_low_noise_SC_for_1300nm_OCT.pdf
DOIs:
10.1117/12.2282412

A comparative study of noise in supercontinuum light sources for ultra-high resolution optical coherence tomography

Supercontinuum (SC) light is a well-established technology, which finds applications in several domains ranging from chemistry to material science and imaging systems [1-2]. More specifically, its ultra-wide optical bandwidth and high average power make it an ideal tool for Optical Coherence Tomography (OCT). Over the last 5 years, numerous examples have demonstrated its high potential [3-4] in this context. However, SC light sources present pulse-to-pulse intensity variation that can limit the performance of any OCT system [5] by degrading their signal to noise ratio (SNR). To this goal, we have studied and compared the noise of several SC light sources and evaluated how their noise properties affect the performance of Ultra-High Resolution OCT (UHR-OCT) at 1300 nm. We have measured several SC light sources with different parameters (pulse length, energy, seed repetition rate, etc.). We illustrate the different noise measurements and their impact on a state of the art UHR-OCT system producing images of skin. The sensitivity of the system was higher than 95 dB, with an axial resolution below 4μm.

General information
State: Published
Organisations: Department of Photonics Engineering, Fiber Sensors and Supercontinuum Generation, NKT Group, University of Kent
Contributors: Maria J., S., Bravo Gonzalo, I., Bondu, M., Engelsholm, R. D., Feuchter, T., Moselund, P. M., Leick, L., Bang, O., Podoleanu, A.
Number of pages: 6
Publication date: 2017

Host publication information
Title of host publication: Proceedings of SPIE
Noise study of all-normal dispersion supercontinuum sources for potential application in optical coherence tomography

Commercially available silica-fiber-based and ultra-broadband supercontinuum (SC) sources are typically generated by pumping close to the zero-dispersion wavelength (ZDW) of a photonic crystal fiber (PCF), using high-power picosecond or nanosecond laser pulses. Despite the extremely broad bandwidths, such sources are characterized by large intensity fluctuations, limiting their performance for applications in imaging such as optical coherence tomography (OCT). An approach to eliminate the influence of noise sensitive effects is to use a so-called all-normal dispersion (ANDi) fiber, in which the dispersion is normal for all the wavelengths of interest. Pumping these types of fibers with short enough femtosecond pulses allows to suppress stimulated Raman scattering (SRS), which is known to be as noisy process as modulation instability (MI), and coherent SC is generated through self-phase modulation (SPM) and optical wave breaking (OWB). In this study, we show the importance of the pump laser and fiber parameters in the design of low-noise ANDi based SC sources, for application in OCT. We numerically investigate the pulse-to-pulse fluctuations of the SC, calculating the relative intensity noise (RIN) as a function of the pump pulse duration and fiber length. Furthermore, we experimentally demonstrate the role of the fiber length on the RIN of the ANDi SC, validating the results calculated numerically. In the end, we compare the RIN of a commercial SC source based on MI and the ANDi SC source developed here, which shows better noise performance when it is carefully designed.
visual contrast obtained with the two technologies is achievable by increasing the readout time of the camera to include a sufficient number of QS-SC pulses.
Projects:

Low noise femtosecond supercontinuum sources
Bravo Gonzalo, I., PhD Student, Department of Photonics Engineering
Bang, O., Main Supervisor, Department of Photonics Engineering
Engsig-Karup, A. P., Supervisor, Department of Applied Mathematics and Computer Science
Sørensen, M. P., Supervisor, Department of Applied Mathematics and Computer Science
Lægsgaard, J., Examiner, Department of Photonics Engineering
Dudley, J. M., Examiner
Genty, G., Examiner
Dudley, J. M., Examiner
Genty, G., Examiner
Grundforskningsfonden
01/09/2015 → 07/11/2018
Award relations: Low noise femtosecond supercontinuum sources
Project: PhD

Activities:

Polarization noise study in all-normal dispersion fiber supercontinuum generation
Period: 29 Jan 2018
Ivan Bravo Gonzalo (Speaker)
Rasmus Dybbro Engelsholm (Other)
Andreas Falkenstrøm Mieritz (Other)
Mads Peter Sørensen (Other)
Ole Bang (Other)
Department of Photonics Engineering
Fiber Sensors and Supercontinuum Generation
Department of Applied Mathematics and Computer Science
Dynamical Systems
Center for Intelligent Drug Delivery and Sensing Using Microcontainers and Nanomechanics

Related event
29/01/2018 → …
Activity: Talks and presentations › Conference presentations

Ultra-low noise supercontinuum source for ultra-high resolution optical coherence tomography at 1300 nm
Period: 28 Jan 2018
Ivan Bravo Gonzalo (Speaker)
Michael Maria (Other)
Rasmus Dybbro Engelsholm (Other)
Thomas Feuchter (Other)
Lasse Leick (Other)
Peter Morten Moselund (Other)
Adrian Podoleanu (Other)
Ole Bang (Other)
Department of Photonics Engineering
Fiber Sensors and Supercontinuum Generation

Related event
SPIE Photonics West 2018: SPIE BIOS: Design and Quality for Biomedical Technologies XI
27/01/2018 → …
Activity: Talks and presentations › Conference presentations

Noise study of all-normal dispersion supercontinuum sources for potential application in optical coherence tomography
Period: 6 Sep 2017 → 9 Sep 2017
Ivan Bravo Gonzalo (Speaker)
Rasmus Dybbro Engelsholm (Other)
Ole Bang (Other)
Department of Photonics Engineering
Fiber Sensors and Supercontinuum Generation
Degree of recognition: International

Related event
2nd Canterbury Conference on Optical Coherence Tomography: Emphasis on broadband sources
06/09/2017 → 08/09/2017
Canterbury, United Kingdom
Activity: Talks and presentations › Conference presentations