Research outputs:

Real-time high-resolution mid-infrared optical coherence tomography

The potential for improving the penetration depth of optical coherence tomography systems by using light sources with longer wavelengths has been known since the inception of the technique in the early 1990s. Nevertheless, the development of mid-infrared optical coherence tomography has long been challenged by the maturity and fidelity of optical components in this spectral region, resulting in slow acquisition, low sensitivity, and poor axial resolution. In this work, a mid-infrared spectral-domain optical coherence tomography system operating at a central wavelength of 4 µm and an axial resolution of 8.6 µm is demonstrated. The system produces two-dimensional cross-sectional images in real time enabled by a high-brightness 0.9- to 4.7-µm mid-infrared supercontinuum source with a pulse repetition rate of 1 MHz for illumination and broadband upconversion of more than 1-µm bandwidth from 3.58–4.63 µm to 820–865 nm, where a standard 800-nm spectrometer can be used for fast detection. The images produced by the mid-infrared system are compared with those delivered by a state-of-the-art ultra-high-resolution near-infrared optical coherence tomography system operating at 1.3 µm, and the potential applications and samples suited for this technology are discussed. In doing so, the first practical mid-infrared optical coherence tomography system is demonstrated, with immediate applications in real-time non-destructive testing for the inspection of defects and thickness measurements in samples that exhibit strong scattering at shorter wavelengths.

General information

Publication status: Published
Organisations: Department of Photonics Engineering, Fiber Sensors & Supercontinuum, Optical Sensor Technology, Upper Austrian Research GmbH, University of Kent
Corresponding author: Petersen, C. R.
Number of pages: 13
Publication date: 1 Dec 2019
Peer-reviewed: Yes

Publication Information

Journal: Light: Science and Applications
Volume: 8
Issue number: 1
Article number: 11
ISSN (Print): 2095-5545
Ratings:
Web of Science (2019): Indexed yes
Original language: English
Electronic versions:
hkkr_s41377_019_0122_5.pdf
DOIs:
10.1038/s41377-019-0122-5
Source: Scopus
Source-ID: 85060523108
Research output: Contribution to journal › Journal article – Annual report year: 2019 › Research › peer-review

Characterization of the NEP of Mid-Infrared Upconversion Detectors

We present a scheme to estimate the noise equivalent power (NEP) of the frequency upconversion detectors (UCDs), detecting mid-infrared (MIR) light. The NEP of UCD is a combined contribution of NEPs from the upconversion process and from the photodetector, used for detecting the upconverted signal. The 2-5 µm MIR range is particularly investigated
in this letter using a bulk periodically poled lithium niobate based CW -intracavity UCD. We measured the NEP of UCD as 20 fW/ Hz at MIR wavelength of 339 μm. We showed that the limiting factor here is not the noise from the upconversion process (estimated NEP is 23 fW/ Hz at 339 μm), but from the electrical noise in the photodetector itself. We also compared the performance of our UCD with previously published results and with market available direct MIR detectors. Additionally, we measured the optical noise of the UCD over its working spectral range (29 -36 μm) and compared with numerical simulation.

General information
Publication status: Published
Organisations: Department of Photonics Engineering, Optical Sensor Technology, Diode Lasers and LED Systems, Lund University, NLIR ApS
Pages: 681-84
Publication date: 2019
Peer-reviewed: Yes

Publication information
Journal: IEEE Photonics Technology Letters
Volume: 31
Issue number: 9
ISSN (Print): 1041-1135
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
Original language: English
Keywords: Infrared detectors, Noise, Nonlinear optical devices, Sensor systems and applications
DOIs:
10.1109/LPT.2019.2904325
Source: FindIt
Source-ID: 2444571741
Research output: Contribution to journal › Journal article – Annual report year: 2019 › Research › peer-review

Mid-Infrared (6 - 10 μm) upconversion in LiInS2 using 1064 nm CW pump
For the first time wide-band mid-infrared (6-10 μm) frequency upconversion in a LiInS2 crystal is obtained using a 1064 nm pump. The absorption spectrum of polystyrene is characterized using a near-infrared grating and a Si-CCD.

General information
Publication status: Published
Organisations: Department of Photonics Engineering, Optical Sensor Technology, NLIR ApS
Contributors: Barh, A., Høgstedt, L., Tidemand-Lichtenberg, P., Pedersen, C.
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: Crystals, Absorption, Laser excitation, Photonic band gap, Gratings, Frequency conversion, Pump lasers
DOIs:
10.1364/CLEO_SI.2018.SM4D.4

Bibliographical note
From the session: Optical Metrology Nonlinear Optical Technologies (SM4D)
Source: FindIt
Source-ID: 2438377002
Research output: Chapter in Book/Report/Conference proceeding › Article in proceedings – Annual report year: 2018 › Research › peer-review

Thermal noise in mid-infrared broadband upconversion detectors
Low noise detection with state-of-the-art mid-infrared (MIR) detectors (e.g., PbS, PbSe, InSb, HgCdTe) is a primary challenge owing to the intrinsic thermal background radiation of the low bandgap detector material itself. However, researchers have employed frequency upconversion based detectors (UCD), operable at room temperature, as a promising alternative to traditional direct detection schemes. UCD allows for the use of a low noise silicon-CCD/camera to improve the SNR. Using UCD, the noise contributions from the nonlinear material itself should be evaluated in order to
estimate the limits of the noise-equivalent power of an UCD system. In this article, we rigorously analyze the optical power generated by frequency upconversion of the intrinsic black-body radiation in the nonlinear material itself due to the crystals residual emissivity, i.e. absorption. The thermal radiation is particularly prominent at the optical absorption edge of the nonlinear material even at room temperature. We consider a conventional periodically poled lithium niobate (PPLN) based MIR-UCD for the investigation. The UCD is designed to cover a broad spectral range, overlapping with the entire absorption edge of the PPLN (3.5 - 5 µm). Finally, an upconverted thermal radiation power of similar to 30 pW at room temperature (similar to 30 degrees C) and a maximum of similar to 70 pW at 120 degrees C of the PPLN crystal are measured for a CW mixing beam of power similar to 60 W, supporting a good quantitative agreement with the theory. The analysis can easily be extended to other popular nonlinear conversion processes including OPO, DFG, and SHG. (C) 2018 Optical Society of America under the terms of the OSA Open Access Publishing Agreement

General information
Publication status: Published
Organisations: Department of Photonics Engineering, Optical Sensor Technology
Contributors: Barh, A., Tidemand-Lichtenberg, P., Pedersen, C.
Pages: 3249-3259
Publication date: 2018
Peer-reviewed: Yes

Publication information
Journal: Optics Express
Volume: 26
Issue number: 3
ISSN (Print): 1094-4087
Ratings:
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
Original language: English
Electronic versions:
oe_26_3_3249.pdf
DOIs:
10.1364/OE.26.003249
Source: FindIt
Source-ID: 2396035714
Research output: Contribution to journal › Journal article – Annual report year: 2018 › Research › peer-review

Concave Grating Enabled Compact Mid-IR Upconversion Spectrometer
The paper demonstrates a wide-band (3.6 - 4.8 µm) compact mid-infrared grating spectrometer combining a nonlinear frequency upconversion process and a flat-field aberration corrected concave grating with overall system dimension of 25cm×50cm.

General information
Publication status: Published
Organisations: Department of Photonics Engineering, Optical Sensor Technology
Contributors: Barh, A., Tidemand-Lichtenberg, P., Pedersen, C.
Publication date: 2017

Host publication information
Title of host publication: Proceedings of Frontiers in Optics 2017
Publisher: OSA - The Optical Society
Article number: FTu5D.3
(OSA, Technical Digest).
DOIs:
10.1364/FIO.2017.FTu5D.3
Source: PublicationPreSubmission
Source-ID: 140590684
Research output: Chapter in Book/Report/Conference proceeding › Article in proceedings – Annual report year: 2017 › Research › peer-review

Inherent Limitations in Mid-Wave and Long-Wave-IR Upconversion Detector
Inherent limitations in terms of optical losses, selection of nonlinear crystal(s), detection efficiency and pumping conditions in mid-wave (3-5 µm) and long-wave (8-12 µm) infrared frequency upconversion modules are investigated in this paper.

General information
Thermally controlled mid-IR band-gap engineering in all-glass chalcogenide microstructured fibers: a numerical study:

**Paper**

Presence of photonic band-gap (PBG) in an all-glass low refractive index (RI) contrast chalcogenide (Ch) microstructured optical fibers (MOFs) is investigated numerically. The effect of external temperature on the position of band-gap is explored to realize potential fiber-based wavelength filters/sensors at functional mid-IR spectral range. The cross-sectional geometry of the MOF is formed by considering a Ch glass to form the overall background cross-section as well as the central fiber core. The core region is surrounded by periodically arranged (hexagonal pattern) smaller holes, which are assumed to be filled up with another Ch glass. Thermally compatible and fabrication suitable, two Ch glasses are chosen, one (higher RI) as background material and the other (of lower RI) to fill up the holes. Two sets of such pairs of thermally compatible Ch-glasses are considered as fiber structural materials with relative RI contrast of ~12% and ~24%. For both such low RI contrast hexagonal structures, PBG appears only for suitable finite values of longitudinal wave vector. The structures are suitable to realize band-gap at mid-IR wavelengths and specifically optimized for operation around the ~2 μm region. Then the temperature sensitivity of band-gaps is investigated to design fiber-based mid-IR wavelength filters/sensors.

**General information**

Publication status: Published
Organisations: Department of Photonics Engineering, Optical Sensor Technology, Indian Institute of Technology, Kharagpur, Mahindra École Centrale, Naval Research Laboratory
Number of pages: 7
Publication date: 2017
Peer-reviewed: Yes

**Publication information**

Journal: Journal of Optics
Volume: 19
Issue number: 6
Article number: 065603
ISSN (Print): 1464-4258
Ratings:
BFI (2017): BFI-level 1
Scopus rating (2017): CiteScore 2.13 SJR 0.839 SNIP 0.866
Web of Science (2017): Impact factor 2.323
Web of Science (2017): Indexed yes
Original language: English
Keywords: Microstructured optical fiber, Photonic band-gap, Infrared optics, Chalcogenide glasses
DOIs:
10.1088/2040-8986/aa6cc3
Source: FindIt
Source-ID: 2358509504
Research output: Contribution to journal > Journal article – Annual report year: 2017 > Research > peer-review

Ultra-broadband mid-wave-IR upconversion detection

In this Letter, we demonstrate efficient room temperature detection of ultra-broadband mid-wave-infrared (MWIR) light with an almost flat response over more than 1200 nm, exploiting an efficient nonlinear upconversion technique. Black-body
radiation from a hot soldering iron rod is used as the IR test source. Placing a 20 mm long periodically poled lithium niobate crystal in a compact intra-cavity setup (> 20 WCW pump at 1064 nm), MWIR wavelengths ranging from 3.6 to 4.85 μm are upconverted to near-infrared (NIR) wavelengths (820-870 nm). The NIR light is detected using a standard low-noise silicon-based camera/grating spectrometer. The proposed technique allows high conversion efficiency over a wider bandwidth without any need for a shorter crystal length. Different analytical predictions and numerical simulations are performed a priori to support the experimental demonstrations. (C) 2017 Optical Society of America

Application-specific specialty microstructured optical fibers for mid-IR and THz photonics (Invited)
A review of several of our designed specialty microstructured optical fibers (MOFs) for mid-IR and THz generation and transmission including high power transmission is presented. Extensive results on performance of the designed MOFs are described.
Design of a Polymer-Based Hollow-Core Bandgap Fiber for Low-Loss Terahertz Transmission

We use numerical simulations to design a hollow-core microstructured polymer optical fiber (HC-mPOF) suitable for broadband, terahertz (THz) pulse transmission with relatively low losses and small dispersion. The HC-mPOF consists of a central large air-core surrounded by periodically arranged wavelength-scale circular air holes in a hexagonal pattern, embedded in a uniform Teflon matrix. The THz guidance in this fiber is achieved by exploiting the photonic bandgap (PBG) effect. In our low index contrast Teflon-air (1.44:1) hexagonal periodic lattice, the PBG appears only for a certain range of non-zero values of the longitudinal wavevector. We have achieved PBG over a broad spectral range (bandwidth similar to 400 GHz) ranging from 1.65 to 2.05 THz in the proposed HC-mPOF. The achievable loss coefficient in our designed HC-mPOF is

Room temperature Up-conversion detection of a broadband Mid-IR source

The paper presents efficient up-conversion based room temperature detection of a broadband mid-infrared light source, ranging from 3.6 ~ 4.9 μm, exploiting nonlinear sum frequency generation in a periodically poled lithium-niobate crystal.
Concave Grating Enabled Compact Mid-IR Upconversion Spectrometer
Period: 18 Sep 2017 → 21 Sep 2017
Ajanta Barh (Guest lecturer)
Department of Photonics Engineering
Optical Sensor Technology
Degree of recognition: International
Links:

Inherent limitations in mid-wave and long-wave-IR upconversion detector
Period: 18 Sep 2017 → 21 Sep 2017
Ajanta Barh (Guest lecturer)
Department of Photonics Engineering
Optical Sensor Technology
Links: