Broadband Near Infrared Supercontinuum for Z-Scan Nonlinear Spectrometer

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Abstract: High-spectral-irradiance infrared supercontinuum with fundamental Gaussian spatial profile was generated in Krypton gases. We demonstrate its usefulness for Z-scan nonlinear spectroscopy in the 800-1600nm spectral range using GaAs and CS_2.
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1. Introduction

Carrying out nonlinear refraction and absorption measurements, such as Z-scan, over a broad spectral range can be extremely time-consuming. This is mostly because beam realignment and spatial characterization for each wavelength are needed when optical parametric devices are used for this purpose. The necessity of broadly tunable and stable laser sources with sufficiently high power for nonlinear material characterization is the starting point for this work. Our interest lies in using a single beam that contains a broadband spectrum with sufficient spectral energy density to replace optical parametric generators/amplifiers. Single-filament supercontinuum (SC) generation is a good candidate for this purpose. From such a beam, we can select different wavelengths without the need for realignment by only changing a series of narrow bandpass filters. The simplicity of the method and the lack of need to realign between wavelengths allows the possibility of automation for faster measurements of complete nonlinear optical spectra.

Supercontinua generated in condensed matter has been comprehensively demonstrated, but the inability to generate high-spectral-irradiance at all wavelengths has limited the application as a tunable source for nonlinear optics experiments. This is partly due to due optical damage in solids from the pump beam [1]. This problem can be overcome with the use of gases. SC generated in gases for Z-scans was previously presented by Balu et al.[2], where spectral broadening across the visible was demonstrated by pumping at a wavelength of 775 nm with femtosecond pulses. Ensley et al. [3] also demonstrated energy and spectral enhancement in the visible and near infrared (IR) spectra by pumping at 780 nm and by introducing a weak seed pulse at ~650 nm, which extended the usable range of SC from 300 nm to 1100 nm.

In this work, we present IR-SC generation in the range 800 – 1600 nm by pumping at 1800 nm in Krypton (Kr) gas, and prove its applicability by performing Z-scans to measure two-photon absorption (2PA) in Gallium Arsenide (GaAs) and nonlinear refraction (NLR) in carbon disulfide (CS_2).

2. Experimental details

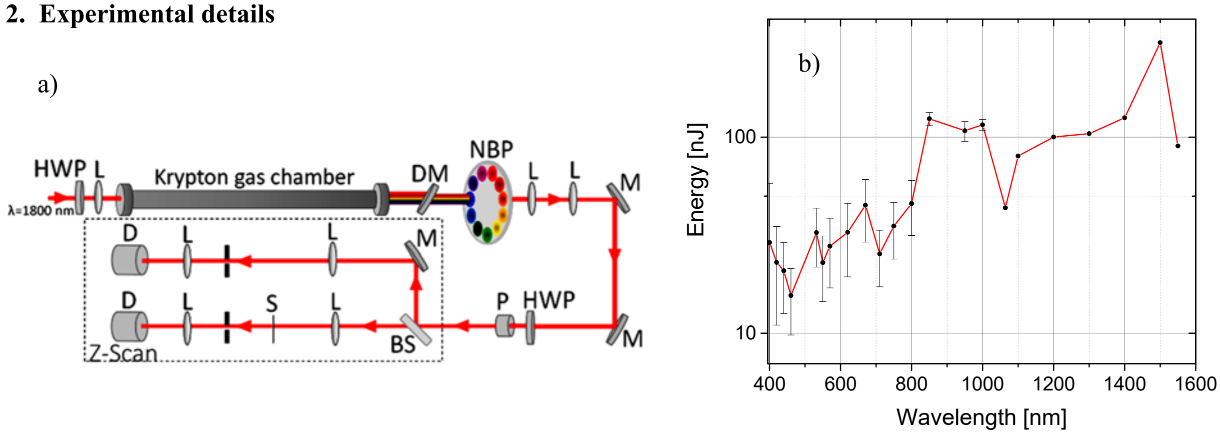

Fig.1. a) Schematic of WLC and Z-scan experimental setup: HWP: half-wave-plate; L: lens; DM: Dichroic Mirror; NBP: Narrow Bandpass Filter wheel; M: mirror; P: polarizer filter; BS: beam splitter; S: sample; D: detector; b) SC Energy measured after the NBP filters.

Figure 1 (a) shows the experimental setup for SC generation: a Ti:Sapphire laser system (Coherent Legend Elite Duo HE+) and a commercial OPA/G (lightconversion, HE–TOPAS) are used for producing femtosecond pulses at 1800 nm with a bandwidth of 130 nm (FWHM). The repetition rate is 1 kHz. The beam is weakly focused by a 1.0 m planoconvex lens into a 1.8 m chamber filled with krypton gas at 3.7 atm. The energy used to generate a stable SC was 450 μJ at the input of the chamber. The SC is directed toward a computer-controlled filter wheel with different bandpass filters with the purpose of selecting wavelengths prior to the sample to eliminate frequency nondegenerate nonlinearities[4]. Finally, the beam is directed to the Z-Scan[5] setup for 2PA and NLR measurements. A dichroic mirror (THORLABS® DMSP1500) at the output of the chamber blocks the pump wavelength, decreasing transmission for wavelengths at 1500 nm and longer.

Figure 1 (b) shows the energy of the generated SC, transmitted by each bandpass filter (nominally ~10 nm) after the dichroic mirror. The dichroic mirror used prevented the continuum from being observed in the 1500 nm – 1800 nm, range, but we anticipate that by using a different filter to block the 1800 nm pump, the SC energy available in this range will be significant.

3. Results and discussion

The SC generated was sufficiently stable and had high enough quality beam profiles to perform closed and open-aperture Z-Scans. In Figure 2(a) we demonstrate measurements of 2PA of a 0.5 mm thick sample of GaAs at a wavelength of 1400 nm. A 10 cm focal length lens was used for focusing into the sample. Because we did not yet measure the pulse width, we use literature values of the 2PA coefficient in GaAs [6], which yields a pulse width of 250 fs. In Figure 2(b) we show the closed aperture Z-scan of a 1 mm sample of CS_2. Using the pulse width obtained from the GaAs, we fit the NLR coefficient (n_2) for CS_2 as 7.0×10^{-19} m^2/W $\pm 10\%$, in agreement with ref [7].

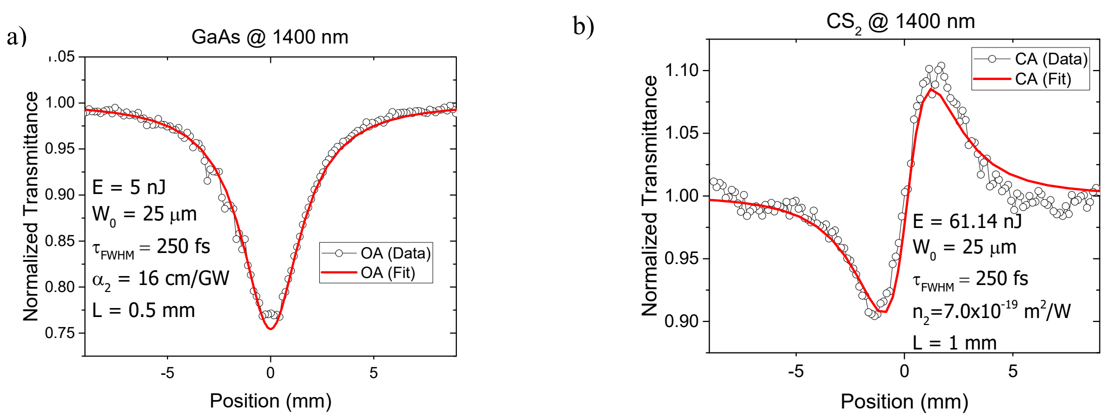

Fig.2. Experimental results for 1400nm wavelength. a) Open-aperture Z-scans of GaAs and b) Closed-aperture for CS_2. The circles are the experimental data and the lines are the fits obtained.

Finally, we have generated SC with sufficient beam quality and spectral-irradiance in the near-infrared spectral region to allow tunable Z-scan measurements of nonlinear refraction and absorption across the near infrared. Extension of useful wavelength range to near the 1800 nm pump will be possible with a different spectral filter.

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4. References

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