Near-IR White Light Continuum for Broadband Z-Scan Nonlinear Spectroscopy

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Abstract: Weakly focused, near mJ, 1800nm femtosecond pulses in a 1.8m Krypton gas chamber generates a high-spectral-irradiance, Gaussian spatial profile continuum for nonlinear spectroscopy in the 800-1600nm range. We demonstrate its usefulness with Z-scans on GaAs.
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1. Introduction

Performing nonlinear spectroscopy using techniques such as Z-scan, normally use optical parametric devices which usually require realignment and beam characterization for each wavelength used, and the beam profile is often not reproducible after realignment. Thus, the spectral characterization of the nonlinear optical properties of materials is difficult and time-consuming. The necessity of broadband and stable power laser sources for nonlinear material characterization is the starting point for this work. Our interest lies in using a single light source that contains a broadband spectrum with enough spectral energy density that it can replace optical parametric generators/amplifiers. For this reason, single-filament white light continuum (WLC) generation is a good candidate. By only changing a series of narrow band filters, we can select different wavelengths without the need for realignment. Additionally, automation can be possible for faster measurements of complete nonlinear optical spectra.

WLC in condensed materials in the mid- IR band has been demonstrated thoroughly, but the inability to generate high-spectral-irradiance at those wavelengths has limited their use due to low damage thresholds. WLC generated in gases for use in Z-scans was previously presented by Balu *et al.* [1], where spectral broadening across the visible was demonstrated by pumping at 775 nm. Ensley *et al.* [2] also demonstrated energy and spectral enhancement in the visible and near infrared (IR) spectra by pumping at 800 nm and using a week seed beam at 650 nm, the introduction of the weak seed pulse extended the usable range from 300 nm to 1100 nm. In this work, we present WLC generation in Krypton (Kr) gas with high spectral energy density and prove its applicability by performing degenerate two-photon absorption (2PA) spectral measurements of Gallium Arsenide (GaAs) in the near-infrared.

2. Experimental details

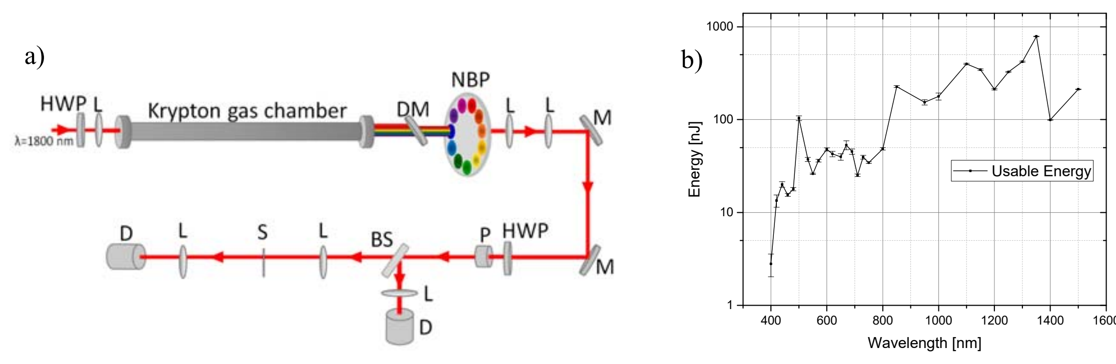

Fig.1. a) Schematic of WLC and Z-scan experimental setup: HWP: half-wave-plate; L: lens; DM: Dichroic Mirror; NBP: Narrow Bandpass Filter wheel; M: mirror; P: polarizer filter; BS: beam splitter; S: sample; D: detector; b) WLC Energy measured after the NBP filters.

Figure 1 (a) shows the experimental setup for WLC generation: a Ti:Sapphire laser system (Coherent Legend Elite Duo HE+), as well as the TOPAS-HE, is used for producing ~1.1 mJ, pulses at 1800 nm with a FWHM bandwidth of 130 nm), at a 1 kHz repetition rate. The beam is weakly focused into a 1.8 m chamber filled with krypton gas at 4.8 atm by a 1.0 m plano-convex lens. The energy used to generate a stable WLC was 440 µJ at the input of the chamber. Then, the WLC 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 [3]. Finally, the beam is directed to the open-aperture (OA) Z-Scan [4] setup for 2PA measurements. The dichroic mirror

(THORLABS® DMSP1500) at the output of the chamber blocks the pump wavelength, decreasing transmission for wavelengths 1500 nm and longer.

Figure 1 (b) shows the energy of the generated WLC, 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 WLC energy available in this range will be significant.

3. Results and discussion

To verify the usability of the generated near-IR WLC, we demonstrate measurements of 2PA of the semiconductor GaAs for the infrared. The thickness of the GaAs sample used is 0.5 mm. A 10 cm focal length lens is used for focusing into the sample

In Figure 2 we show examples of experimental results for 2PA measurements in the infrared region using the WLC generated with Kr gas. The empty circles are the experimental data and the lines are the fits obtained for the OA Z-Scans.

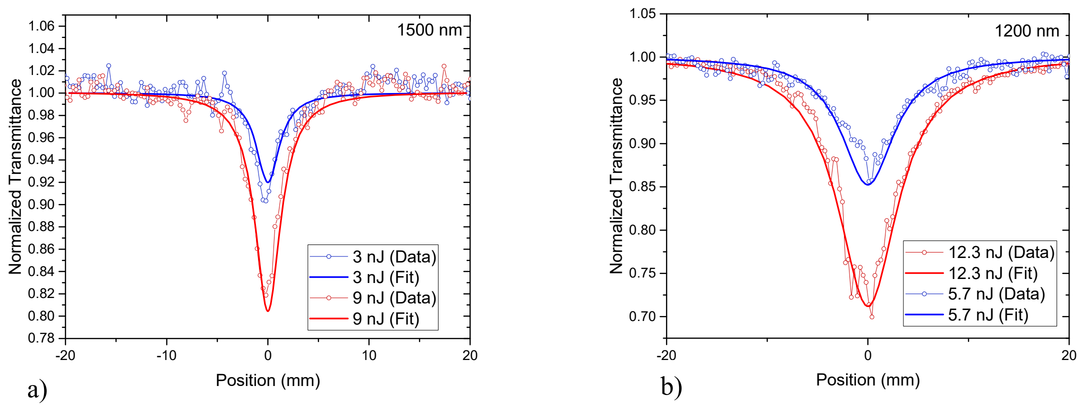

Fig.2. Open-aperture Z-scans of GaAs at 1500 and 1200nm along with fits for α_2(1500nm)=9 cm/GW and α_2(1200nm)=16.5 cm/GW

Figure 2 shows two Z-scans at each wavelength using the same value of the 2-photon absorption coefficient α_2, ensuring negligible contributions from carrier nonlinearities. In figure 2 (a) we used energies of 3.0 and 9.0 nJ for 1500 nm, which resulted in α_2(1500nm)=(9±2) cm/GW, and for (b) we used 5.7 and 12.3 nJ for 1200 nm, which resulted in α_2 (1200nm)=(16±4) cm/GW. These values are in close agreement with our experimental predictions and previous measurements [5].

Finally, we can conclude that the WLC generated in this work is high quality with high-spectral-irradiance in the near-infrared spectral region allowing nonlinear spectroscopic measurements of nonlinear optical properties of materials. Extension of the useful wavelengths to near the 1800nm pump should be possible with a different spectral filter.

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5. References

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