Degenerate Z-scan measurements with white-light continuum

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Abstract

Here we present a new Z-scan technique for direct measurements of nonlinear absorption spectra. This technique is based in the use of an intense single white-light continuum (WLC) beam as the coherent broadband light source. The WLC beam is focussed and the nonlinear sample is scanned along the beam propagation direction, as the Z-scan technique requires. Since each color is focussed in different z-position, the degeneracy of the nonlinearity is preserved. Here we have measured the nonlinear absorption spectrum of a two azobenzene solution from 400 to 750nm. These solutions present a strong saturable absorption (SA) process around the linear absorption band.

Introduction

The measurement of nonlinear properties at function of wavelength is very important in the viewpoint of molecular design and application of optical materials [1]. To measure these properties a tunable pulsed laser with high peak power is necessary as light source. Tunable optical parametric amplifier (OPA) pumped by Ti:sapphire femtosecond laser is one of the appropriated candidate for this purpose. This light source is able to reach a broad tunability range, typically, from the visible to infrared region. However, since this source allows measurements only for a discrete wavelength, the time to measure absorption spectra in broad range is long.

It is well know that many transparent liquid and solid media, a white-light continuum (WLC) generation can be efficiently produced by using high peak power ultrashort laser pulse of femtosecond duration [2]. Initially, this WLC source has been employed to measure the linear absorption spectra of sample materials. The advantage of this approach is the elimination of need for spectral tunability and scanning mechanism.

Here we report a new Z-scan technique capable to measure the nonlinear absorption spectra using a single WLC beam. In this approach, a powerful WLC beam is generated in a water cell and next used in the Z-scan measurements. Since different spectral components of the continuum beam is focused at different area of the sample due to chromatic aberration, the nondegenerate nonlinear processes among these different spectral components can be eliminated.

Materials and Methods

In our experiments distilled water was used as the nonlinear medium to provide the WLC generation. As pump source for this continuum generation was used a focused ultrashort pulse laser beam provides by a femtosecond amplified laser system. The femtosecond laser was a commercial chirped pulse amplified CPA 2001 system from Clark MRX Inc. The system cans delivery pulses up to 0.8 mJ with 150fs at 775nm at 1KHz repetition rate. The 150 fs at 775nm laser beam was focused by f=30 cm lens into the center of a 4cm long water cell. The output continuum light beam was re-collimated via an f=10 cm lens. In sequence, the WLC beam has been used in the Z-scan measurements. The focused WLC beam passes through the sample and then it is focused into the small spectrometer. By scanning the sample along z-direction each spectral component generate a typical Z-scan signature in accord with it nonlinear property.

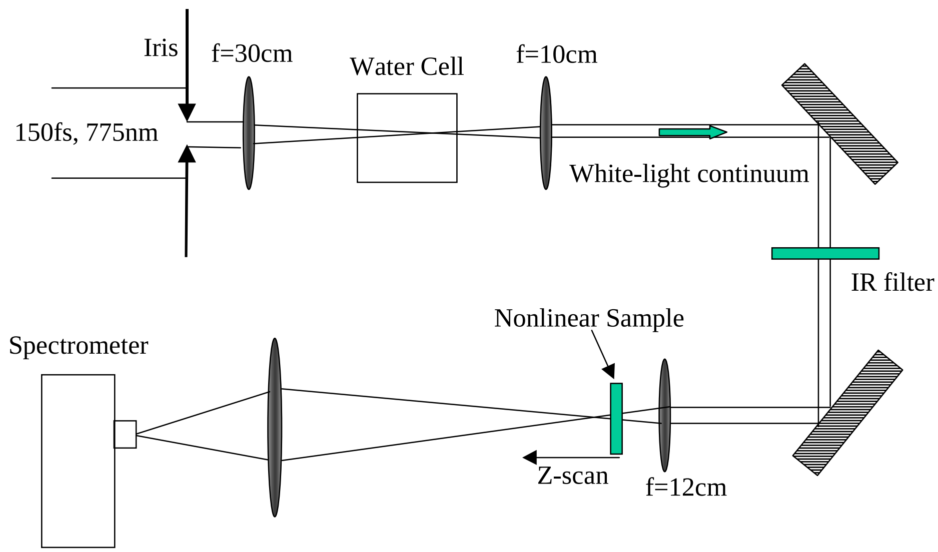

Figure 1: Experimental setup for white-light continuum generation and the Z-scan measurements.

The spectrometer used in our experiments was the USB 2000 from Ocean Optics. Its resolution of ~0.5 nm is enough to fulfil the purpose of our experiments.

We also performed the traditional Z-scan measurements to determine the nonlinear absorption spectra using a tunable OPA light source. Our commercial OPA, TOPAS from Quantronix was pumped by our Ti:sapphire laser delivering femtosecond pulses tunable from 460 to 2600nm. In this case, for each select single wavelength we have done the Z-scan measurements.

Results and Discussions

The samples measured in this work were DO3 and DR19-Cl azobenzene dye with same concentration of 0.04 mg/ml. These azobenzene molecules present a photoinduced cis-trans isomerization and a strong saturable absorption process at resonance wavelengths.

Using about 0.1 mJ of 150 fs Ti:sapphire laser pulse we were able to generate about 3 μJ of WLC in the visible range using the 4 cm length water cell. An IR filter (KG 3) was used to remove the strong 775 nm pump pulse. The WLC spectrum is showed in the fig. 2.

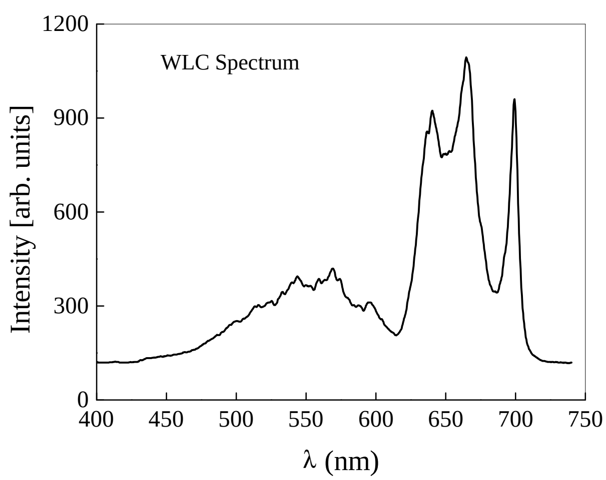

Figure 2: The spectrum of the WLC after passes in the IR filter used in our experiments.

Figure 3 shows the Z-scan signatures for the WLC spectrum for both samples. These signatures were obtained simultaneously as the samples are scanned. In sequence we also performed the traditional discreet Z-scan measurements using the tunable OPA. We have measured from 460 to 650 nm in 5 nm step. The power used was kept fix at 0.05 μJ for all color. As we can see from the fig. 3 exist a good agreements between the two methods.

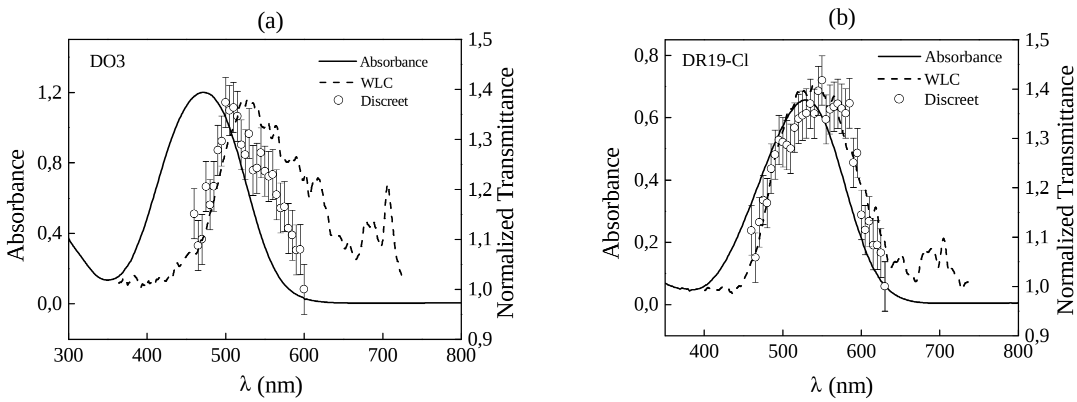

Figure 3: Linear (solid line) and nonlinear absorption spectra of DO3 (a) and DR19 (b) dye solutions. The dashed line and the circle were obtained from WLC Z-scan and discreet Z-scan technique, respectively.

It worthwhile to stress that each discreet Z-scan takes about the same time to be performed as the WLC Z-scan. In which case, the discreet Z-scan takes as much time as the number of wavelength we choose to measure.

Conclusions

In summary, we have demonstrated a new experimental method for measuring the nonlinear absorption spectra in a single measurement using white-light continuum beam. We have obtained a good agreement between the results obtained by the method using a WLC and the traditional discreet measurements. These results allow concluding that the Z-scan using WLC is a very fast and simple method to determine the nonlinear absorption spectra of any nonlinear samples.

Acknowledgements

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