Stable UV-extended Supercontinuum Generation in a Bulk Material by Picosecond Pulses

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Abstract: Stable UV-extended supercontinuum generation by self-action of picosecond pulses in bulk materials is demonstrated. The stability and spectral properties of the continuum show a strong dependence on the focusing parameters in 120-mm long CaF_2 rod.
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Over the last decade the generation of coherent optical continuum has had a substantial impact on numerous applications including time-resolved broadband spectroscopy, optical tomography, broadband LIDAR, utrabroadband parametric amplification and pulse compression, near-field spectroscopy of nanoparticles, etc. Typically, such white-light supercontinuum (SC) is produced by femtosecond pulses in bulk materials or by using photonic-crystal silicon fiber technology, the latter being applicable to longer pulse durations, on the picosecond or nanosecond time scale. Producing supercontinuum extending to the ultraviolet range below 450 nm, however, is much more challenging. The above wavelength range is of interest since the spectra would then span the entire visible range and include a useful spectral band for transient abortion spectroscopy applications. For fs-pump pulses, it has been shown already that using wideband gap bulk materials such as CaF_2 is a promising approach to generate UV-extended fs-supercontinuum [1-3]. Although the SC generation using picosecond pulses has the advantage of using widely available ps-lasers, the conditions for obtaining a stable and robust SC in a bulk material have not been comprehensively studied compared to the use of femtosecond pump pulses and the recently obtained results of ps-SC generation are limited on the short wavelength side to around 500 nm [4-5].

Here we report on a stable UV-extended supercontinuum generation by self-action of picosecond pulses in a bulk material (120-mm long CaF_2 rod). The dependence of SC spectra on the pump beam parameters in the CaF2 crystal has been studied experimentally. A comparison between a SC generation using ps-pulses at 1064 nm and 532 nm, respectively, is presented.

Figure 1 shows the experimental set-up. The pump pulses are obtained using a laser system consisting of a $Nd:YVO_4$ oscillator and a $Nd:YVO_4$ regenerative amplifier. The laser system generates pulses with a duration of 7 ps (FWHM) and a pulse energy of 200 μJ at a repetition rate of 60 Hz. A variable attenuator and a diaphragm are used to reduce the pulse energy. Then the laser beam is focused in a 120-mm-long CaF_2 crystal using a focusing lens L1 (f = 200 mm) resulting in a pump spot with a diameter of 150 μm. The crystal is mounted on an XYZ translation stage. The X-Y translators for a fixed Z position enable the motion of the crystal in a direction perpendicular to the optical axis in order to avoid damages of the crystal. The Z- position is varied in order to study the SC properties as a function of the pump waist position within crystal. The supercontinuum is filtered using a dichroic filter and subsequently focused in the fiber spectrometer using a focusing lens L2.

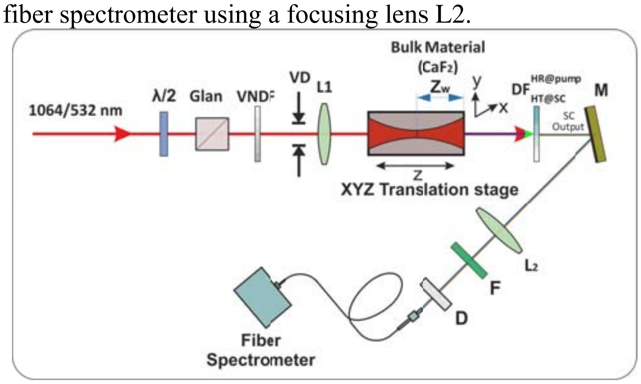

Fig. 1: Experimental set-up: VNDF: variable neutral density filter, VD: variable diaphragm, L1: focusing lens, DF: dichroic filter, M: folding mirror, L2: focusing lens, F: filter, D diaphragm.

A fraction of the laser output (90-140 μJ) at 1064 nm is focused into a 120 mm thick CaF_2 rod in order to exceed the SC threshold. To reduce the pump intensity, which is around three orders of magnitude higher than the intensity spectral distribution of the generated SC, a custom designed notch filter (DF) has been used.

The SC spectrum changes from bluish to reddish by changing the pump waist position along the crystal axis from the output to the input surface of the crystal, respectively. The blue type of the spectrum with three pronounced peaks around 400 nm (the most outstanding one), 500 nm and 700 nm are observed for pump beam waist positioned within 30-55 mm from the output crystal surface (the black curve in fig.2b, z_w=55mm). When the pump-beam waist position lies between 65 mm and 90 mm, the SC is brighter, more stable and only one broad peak around 500 nm is present in the SC spectrum (Fig. 2a and the red curve in fig. 2b), z_w=85mm). In the case of positioning the pump waist around the crystal input surface, a broad peak at 700 nm dominates the SC spectrum (the blue curve in fig.2b, z_w=105mm). However, if the pump waist is closer to the crystal entrance, damages of the entrance surface are possible.

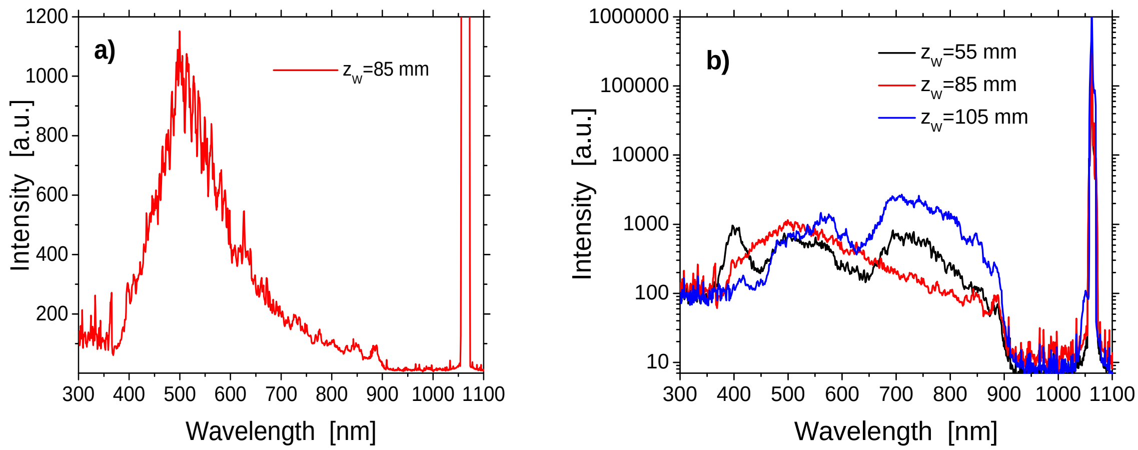

Fig. 2**:** SC spectra obtained using picosecond pulses at 1064 nm, 7 ps-pulse duration: a) SC spectrum for pump waist position in the CaF_2 crystal z_W=85mm, similar SC is observed at z_W(65÷90) mm; b) dependence of the spectrum on the pump waist position in the CaF_2 crystal.

The UV-extension part of the SC spectrum reaches 360 nm for pump pulses at 1064 nm. When a SHG at 532 nm is used, the UV part of the SC spectrum extends down to 330-340 nm. The SC generation input energy threshold as well as optimum pulse energy for a stable operation are reduced to 30 and 36 μJ, respectively, for the same pump beam waist diameter.

In summary, we have observed a SC spectrum and investigated its stability dependence on the position of the pump beam waist along the CaF2 crystal length. Stable UV-extended SC spectrum down to 330 nm has been obtained using ps-pulses from a diode-pumped $Nd:YVO_4$ laser.

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