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A universal broadband and CEP stable seeder for high-power amplifiers.

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Abstract. This work presents a universal seeder architecture based on filamentation and parametric amplification from an Ytterbium pump laser for the generation of pulses with versatile properties in terms of central wavelength, bandwidth, CEP, and contrast for seeding high power amplifiers based on various technologies.

1 Introduction

Recent developments in ultrafast Ytterbium lasers have triggered advances in light sources based on parametric processes, mostly due to their ability to generate a stable, broadband continuum by filamentation in a bulk crystal.

As explained later, the ability of these third-generation sources [1] to produce optical pulses with cutting-edge properties like bandwidth, CEP stability and temporal quality make them ideal candidates for seeding high power amplifiers involving different technologies.

Table 1 summarizes the most relevant amplifier technologies and their key parameters. The present work shows the ability, in a single optical architecture, to produce robust and very stable pulses with the necessary requirements.

Table 1. Table summarizing different amplifier technologies where OPCPA seeders are relevant and their requirements.

	Central wavelength	Bandwidth $1/e^2$ (typical)	CEP	Contrast
Ti:Sa	800 nm	80-100 nm	Yes	Yes
Nd:YLF/ Nd:YAG	~1 µm	< 20 nm	No	Yes
OPCPA	~0.8-2 µm	100-600 nm	Yes	No

2 Seeder optical architecture

The optical seeder that we present in this work is based on a patented method allowing the generation of a broadband and CEP-stable low-energy seed. It relies on a continuum generation in a dielectric crystal followed by a DFG step. This optical architecture is illustrated in Figure 1. It can be summarized as a DFG process between two replicas of the fundamental pulse. The unique approach resides in an all-optical delay management between the two replicas, ensuring a highly stable delay between pulses for robust long-term passive CEP operation, as well as good spectral stability.

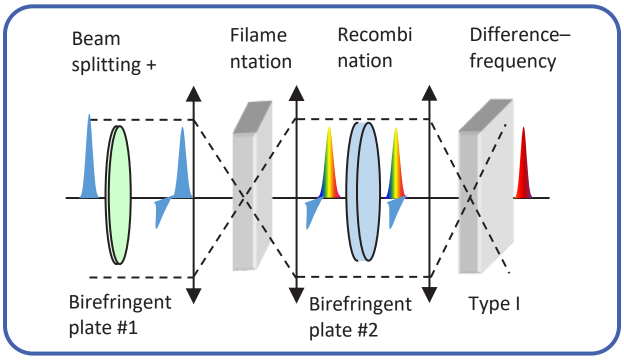

Fig. 1. Illustration of the inline DFG architecture

One of the replicas is broadened by a filamentation process and is used as a pump in the DFG step. The large pump bandwidth ensures the capability to generate broadband spectra, as well as a tuneable central wavelength within a spectral range from 1.4 µm to 2.6 µm.

Following the low-energy seed generation, a two-stage optical parametric amplifier is added to reach the µJ energy level after amplification. An additional second harmonic generation (SHG) step can be added between the two amplification stages to access the 0.7-1.3 µm spectral range.

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This architecture has been tested on a large variety of pump lasers [2, 3]. It always demonstrated robust and stable operation. However, like any other optical parametric process, it is sensitive to pump laser parameters variations like pulse duration or beam divergence. A compact and robust low-power pump is then preferred for long term operation with unchanged parameters.

3 Experimental results

The following experimental results were obtained using the same architecture with different pump lasers.

3.1 Spectral bandwidth

Fig 2 shows typical spectra after a two-stage seeder. Depending on the central wavelength, FTL bandwidths support from 12.5 fs to 30 fs. Fig 2 shows experimental spectra from two different pump lasers. Spectral stability has been tested over several hours and is in the range of 0.5-1% of the spectral bandwidth.

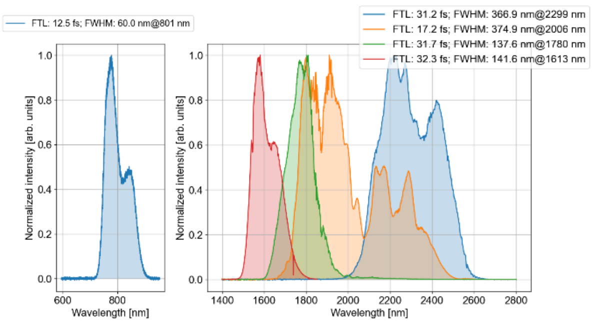

Fig. 2. Examples of seeder spectra at different central wavelengths with corresponding spectral bandwidths.

3.2 CEP stability

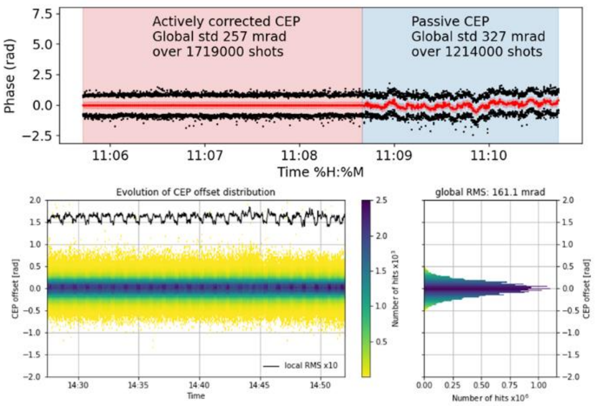

Fig. 3. Top, actively stabilized and passive single shot CEP at 800nm measured at 10 kHz repetition rate, pump laser is a Tangerine (Amplitude). Bottom, actively stabilized CEP measured at 2 µm at 13 kHz repetition rate, pump is a 500W, 52 kHz system from TSL.

Active and passive CEP-stable operation is one of the most challenging parameters to obtain. For long-term and ultra-stable CEP operation, low-power pump lasers are preferred as well.

3.3 Temporal contrast

When seeding amplifiers for high peak power, pulse temporal contrast plays a key role in the control of the physical processes to be studied with such sources. Our universal scheme using wedged amplification crystals and high-quality spectral selection allows to reach very high temporal contrast.

Fig 4 shows the contrast measurements of an 800 nm seeder amplification in a small Ti:Sa CPA system with a gain ~100. These preliminary results already show very good contrast. While some contrast loss contributions are already understood, the overall processes impacting temporal contrast are under investigation by comparing measurements from different amplifiers.

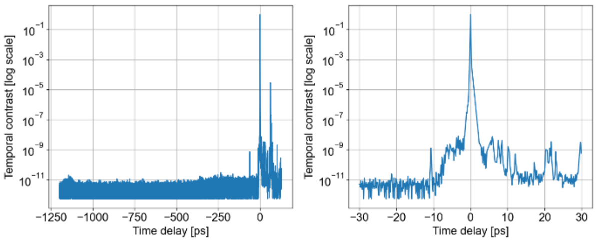

Fig. 4. Temporal contrast measured with the Sequoia autocorrelator for nanosecond range (left) and zoomed around main pulse (right).

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