Development of a High Intensity Yb:YAG Pumped Optical Parametric Chirped Pulse Amplification Laser System
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Abstract
High intensity laser systems are finding many new applications in EM’s in particle generation and acceleration. Fast pulse sources for Linear Plasma Energy Drivers. In some cases, in order to enhance the electric fields associated with the laser-plasmas, stationary wavevectors are advantageous. Thus, there is considerable interest in the development of laser systems in which parametric processes are involved. In the current study we are developing a TW class optical parametric chirped pulse amplifier (OPCPA) system. The pump laser for this system will consist of a femtosecond YAG laser oscillator which will produce the order of 100-fs and amplified in a diode pumped YAG/YAG ceramic slab amplifier setup to up to an energy of around 2 J. A seed pulse for the OPCPA system at a wavelength of around 1550 nm will be created from white light continuum generated from the femtosecond pulse after amplification to the intermediate level. This seed pulse will be amplified in several stages of optical parametric amplification to a final energy of the order of 400 J. The final stage will be incorporated into a pulse duration of the order of 100-fs to give a 4 TW output pulse. The generated system design and initial development tests will be presented and discussed.

OPCPA Systems

• A number of high power optics labs all over the world are building OPCPA systems. The competition is to obtain the plasma while increasing the pulse peak power.

• One of these labs is Center for Free Electron Laser Science (CFEL) in Hamburg, Germany to generate optical waveforms with 5 J pulse duration with 48 TW peak power.

• Other labs like KFP-Institute for Technical Physics, Hannover, Germany, Mediterranean Technology Park, and ICREA-Institute’s Centre de Recerca en Energia (CREA), Santa Anna, Barcelona, Spain; Max-Planck-Institute for Quantumoptics, Garching, Germany; Department of Physile Physics, Ulm University, Munich, Germany; Institute of Applied Physics, Alteur Center of Photonics, Friedrich-Schiller University Jena, Germany[7].

• All of these labs are working on developing the OPCPA systems with peak powers in the range of 15 MW to 10 TW and pulse lengths in the range of 4 to 50 fs.

• We are developing an OPCPA system having its seed generated and extracted from white light continuum (generated from a femtosecond oscillator). The pump pulse is derived from the same seed pulse stretched to the picosecond scale and amplified. Both pump and seed are accurately synchronized, and amplification will be carried out in several non-degenerate parametric mixing inside KTA crystals to obtain a high gain and large bandwidth. The amplified pulse will then be amplified in the final stage to obtain 100-fs pulse with energy of 400 mJ to give a peak output power of 4 TW.

OPCPA Background

• OPCPA technique was first proposed by Dufour et al. in 1992[2]. With a factor of ~2109 without bandwidth compression in a 1-mm crystal, chirped pulses have been parametrically amplified, then they were compressed down to 40-fs to achieve maximum output of ~900 TW.

• Nonlinear Parametric interaction in nonlinear optical crystals has been introduced in 1997 by Douglas MacFarlane at [12] while nonlinear phase matched optical parametric generation is only recently attracting attention as an innovative technique for ultrashort pulse generation[13].

• High power OPCPA systems already are being built with specific features and there are some challenges while designing and engineering OPCPA and they can be summarized as: pumpseed synchronous, which can be accomplished by using tunable pump and seed source; parametric amplification, controlling transverse, dependant on the effective angle and energy; and pumping phase matching and control of the crystal length in order to achieve the modes of the cavity.

• The phase matching and K-vector analysis.

• Mixing optical waves through Optical Parametric Oscillation (OPO’s) process is beneficial only if the interaction can achieve the same phase velocity in the nonlinear medium; i.e. the phase matching condition must be satisfied. During this process conservation of energy and conservation of momentum are required in equations (1) and (2). Therefore, the phase matching for 100 fs pulse wavelength were calculated using equations (3) and (4) based on Sellmeier equation for the indices of refraction of κ1, κ2 and κ3 as in equation (5) [14]. Finally the Kerr nonlinearity across the pump, signal and idler pulse should meet the conditions in equation (2) for phase matching K-vector analysis.

• Conclusion

We are developing a TW OPCPA system. To guarantee that both seed and pump are synchronized, the same femtosecond Yb:YAG master oscillator is used to generate the white light continuum. In continuous seed pulse and also the pulse which will be stretched to the picosecond scale and amplified then used as pump for the OPCPA stages. Thus both pump and seed are accurately synchronized and the phase matching system in the infrared part of the spectrum is a non-collinear phase matched geometry inside KTA crystals that was calculated to obtain a high gain and large bandwidth. The best phase matching angle was found to be 75° at 1030 nm pump wavelength. Therefore, the non-degenerate parametric mixing wave was checked using the K-vector analysis. The amplified pulse will then be compressed down to 100-fs pulse with energy of 400 mJ to give a peak output power of 4 TW.

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References


