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High Peak Power Laser System for ELI NP

High peak power lasers for Ultra High Intensity (UHI) physics have been developed for almost two decades. The first generation of such lasers has been essentially built with Nd:Glass Chirped Pulse Amplifiers (CPA) operating at very low repetition rates (few shots per day).

The last decade has seen the tremendous development of CPA based on Titanium Sapphire crystals pumped by the second harmonic of a Nd:YAG or a Nd:Glass laser. Several groups have recently reported up to 2 PW whereas entirely commercial systems have achieved PW output at a repetition rate of Hz based on Nd:YAG pump laser technology as well as the shortest pulse ever produced by a PW laser, below 25fs. Such systems have already produced outstanding results such as laser-plasma acceleration of electrons up to the record value of 4.25GeV.

The next generation will be based on lasers delivering more peak power than currently including ELI (Extreme Light Infrastructure) Nuclear Physics (ELI-NP) in Romania involving two laser beams of 10PW each (HPLS - High Power Laser System) awarded in July 2013 to Thales by the Romanian Nuclear Physics Institute IFIN-HH.

HPLS is made of two beamlines which will deliver each a main beam of 10PW peak power at 1 shot per minute, with intermediate outputs at 100TW/10Hz and 1PW/1Hz. The two beamlines will be seeded by a common 10mJ Front End.

The 10PW beamline is based on an hybrid scheme involving a first TiSa based kHz CPA of mJ level, a XPW filter for temporal contrast enhancement, an optically synchronized 532nm-pumped OPCPA stage delivering 10mJ at 10Hz capable to enlarge the bandwidth and enhance the temporal contrast and a second TiSa based CPA. Design has taken benefit from a technology transfer agreement with CNRS leading to technical discussion and exchange on the Apollon laser design.

The gain narrowing and wavelength red-shifting effects in TiSa amplifiers is compensated through the insertion of properly designed spectral filters between amplifying stages. In order to reach around 300J of energy per pulse before compression, final amplifier stage between 1 PW intermediate output and 10 PW compressor will be pumped by 800J at 527nm provided by 8 pump lasers (ATLAS-100) delivering each 100J per pulse at 1 shot per minute.

Two Front End beam have been entirely built and characterized. Energy per pulse of more than 10.5mJ has been demonstrated for less than 55mJ pump available at OPCPA BBO crystals showing therefore an overall optical efficiency close to 20% for the OPCPA without any temporal and spatial shaping of the pump beam. The spectral bandwidth is of about 100nm which is more than sufficient in order to seed the following chain of amplifiers. The temporal contrast has been measured and has confirmed the enhancement by at least three orders thanks to the OPCPA.

The Front End beam was used to seed the amplifiers stages corresponding to level required for the 100TW output and the 1PW output with demonstration of the expected performances in term of spectral bandwidth and energy level.The two beams were sent through the compressor with demonstration of a pulse compression at 21fs leading to a peak power of 1.3PW at 1Hz.

Fourteen ATLAS 100 pump lasers (out of sixteen) have been also built and the delivery of more than 100J per pulse with a near flat-top spatial profile has been confirmed for all the units with a pulse energy stability better than 1.5% rms over 8 hours of continuous operation.

Initial results obtained with the system integrated up to the 1PW level within Thales facilities at Elancourt, France, have confirmed the expectations from the design of the HPLS for ELI NP. The final performances are now expected in Romania where the HPLS installation has started in the new facility dedicated to the ELI NP project.

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