

Status of PHELIX Laser Program

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One of the most important milestones of the PHELIX laser program was reached in January 2003, when the required Nova laser components from Lawrence Livermore National Laboratory (LLNL) arrived at GSI. The basis for the transfer was the agreement between the Department of Energy of the United States of America (DOE) and the Federal Ministry of Education and Research of the Federal Republic of Germany (BMBF) to cooperate in energy research, science and technology and development. Within the agreement which was signed on February 20, 1998 the basic science of dense plasma physics using intense ion and laser beams will be explored.

Fig. 1 shows photos of the dismantling and shipping in LLNL and the arrival of the components at GSI.



Figure 1: Transfer of Nova components from LLNL to GSI.

About two thirds of the equipment from LLNL consisted of pulsed power components. Since these parts had been stored in Livermore under open sky for years they required extensive cleaning and refurbishment. Especially the 12 racks containing the ignitron switches had to be totally rebuilt. At the end of 2003 the capacitor bank including the ignitron switches, power supplies and dump system for the double pass amplifier and the booster amplifier were installed and the section required for the double pass was tested successfully using internal dummy loads instead of the flash lamps of the amplifiers. To ensure protection of the high voltage power supplies from possible transients in the discharge circuit we developed mechanical high voltage switches which disconnect the power supply from the capacitor bank after the completion of the charging cycle and which will also be used to distribute the PILC pulse (Pulsed Ionization Lamp Check). Thirty of these switches were manufactured in house and are now in routine

operation. In addition all high voltage connections between the capacitors, high current switches and amplifiers were installed. This allowed the testing of a total number of 100 flash lamps required for the double pass amplifier. These tests were performed in the clean room 10,000 environment of the laser bay before they were installed in the refurbished Nova amplifier housings. For the capacitor and flash lamp tests the discharge currents of the ten circuits that are connected to one amplifier were monitored in parallel. For these tests a new PXI digitizer system with 60 differential channels was set up which will be part of the final PHELIX shot monitoring system. The pulsed power capacitor room and its installations are shown in Fig. 2 together with an inset of the view of the controls console.



Figure 2: Pulsed power capacitor room and controls console

The high amount of stored electrical energy and the related safety hazard as well as the high capital investment of the laser subsystems translate into demanding primary requirements for the PHELIX Control System (PCS). The powerful framework of the PCS was developed by the ECOS group of GSI [1]. The application layer of the PCS will provide the safe operation of a high-energy shot of PHELIX which requires the remote control and supervision of a large number of devices and subsystems. In 2003 the design development of the PCS was started and allowed us to replace the preliminary manual mode of operation that was used for the first test experiments of the pulsed power of the Nova amplifiers.

In preparation of the commissioning of the 2-pass main amplifier, which is planned for 2004, the PHELIX engineering team disassembled the opto-mechanical Nova and pre-amplifier hardware, cleaned it and verified the cleanliness level of a clean room 100 environment prior to

reassembly. The 2-pass amplifier consists of a total of five 31.5 cm diameter disk amplifiers; four of them are equipped with laser glass and fully operational. The beam line of the folded 2-pass amplifier including the 90-degree turning mirrors and their housing are fully sealed and are flushed with nitrogen to avoid degradation of the optics. The alignment of the laser chain was carried out with the help of a 10 W cw Nd:YLF alignment laser. Fig. 3 is a photo of the aligned and sealed 2-pass amplifier.



Figure 3: PHELIX 2-pass amplifier section. The beam line is sealed and flushed with nitrogen

To transport the beam to the experimental areas the design and drawings for the Z6 beam line were started in 2003 and were 90% completed. The set-up of the hardware is in progress. All required components are ordered, most of them are already delivered. Completions of the electric installations, re-building of the ion beam line are additional significant milestones on our road to the first PHELIX experiments at Z6.

An important step towards first laser experiments with PHELIX was the commissioning of the pre-amplifier [2], recompression of amplified pulses to a power level of well above 10 TeraWatt and its successful application as a pump source for a transient collisionally excited x-ray laser [3]. The architecture of the pre-amplifier, shown in fig. 4, follows the design of the Livermore PW front-end [4]. The pre-amplifier provides pulses of up to 8 J, if the stretched fs-front-end beam is amplified. The integration of the system into the final control system and the completion of the engineering effort to further improve the stability and reliability of the system is planned for 2004.

Important for reaching with PHELIX high power densities of the order of 10^{21} W/cm² the improvement of the wave front quality of the laser beam is of crucial importance. As a first step towards the improvement of the beam quality we have integrated a first closed loop adaptive optics system at the end of the pre-amplifier. The system was purchased from the Laboratory of Adaptive Optics of the Russian Academy of Sciences [5]. The concept is described in more detail in a separate contribution in this report [6]. In addition to the anticipated increase of the repetition rate of the pre-amplifier the main goal is the pre-compensation of the aberrations of the main amplifier. In addition to the actively deformable bimorph mirror we have laid out the 0-degree mirror of the 2-pass main amplifier as a static wave front

corrector. The concept of introducing a controlled amount of aberrations on a mirror that will cancel the aberrations of the laser chain by deforming a standard mirror with micrometers was successfully demonstrated in Rutherford at the Vulcan laser [7].

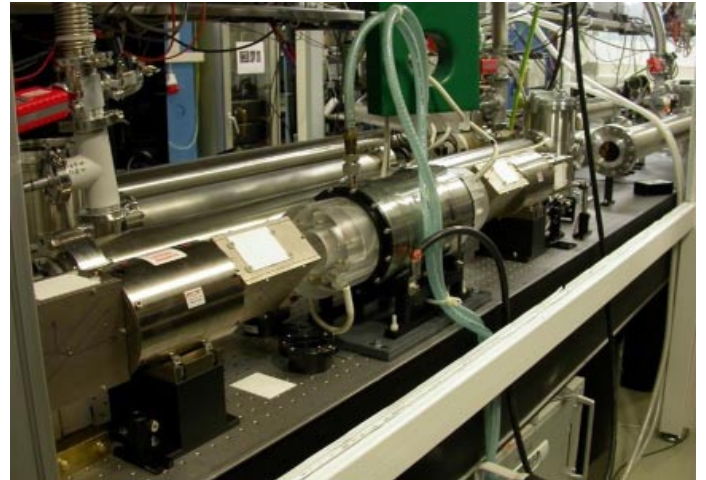


Figure 4: View of pre-amplifier of the 45 mm diameter rod amplifier which was designed and built by LLNL

For the final recompression of the high-energy pulse the main technical challenge is the damage threshold of the compression gratings. The emerging technology of multi-layer dielectric (MLD) gratings offers a significant improvement as compared to gold coated gratings. The large aperture compression gratings had been expected by the end of the year, however delivery was delayed due to recent advancements in the technology. The delivery is expected towards autumn 2004.

The MLD grating based Petawatt compressor necessitates a new pulse stretcher using the same groove density as the compressor gratings. The ray trace modelling of the new stretcher was performed and the grating already delivered. The design goal is to stretch pulses by 250 ps/nm and a transmitted bandwidth of 16 nm.

For the characterization of the fs-pulses an experimental setup was built to perform SPIDER (Spectral Phase Interferometry for Direct Electric field Reconstruction) [8]. This technique allows to obtain full information of a short pulse laser and therefore to unambiguously recover the temporal pulse shape. It will be an important tool for the optimisation of the chirped pulse amplification system.

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