Improved methodology/laser prototype for processing of fine (nanometer sized) structures.

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Abstract. As a result of theoretical analysis of the sub-wavelength defect formation process, we can conclude that such a fine process is based on several nonlinear mechanisms like a two- and three-photon absorption and self-focusing resulting in plasma formation, and therefore the pulse parameters of the writing laser system have extremely critical influence on the successful defect formation and its reproducibility. In this regard we need to maintain pulse energy and pulse duration at the same constant level in a precise manner that will provide a constant level of the pulse peak power as the most crucial parameter. In this regard, we have carried out modifications to the laser setup in the following areas: Holmium regenerative amplifier cavity improvement and seed laser parameters stabilization.

Amplifier performance improvement. All mirrors of the amplifier cavity were replaced because there was a suspicion that over time they would be destroyed, as happened with similar mirrors at the amplifier output. For replacement, the necessary mirrors corresponding to the specifications were purchased. The replacement process was carried out sequentially by one mirror at a time, followed by the testing of the amplifier performance. After replacing all the mirrors, the final tuning of the amplifier was performed, ensuring long-term stable operation without a change in the output power level, as it happened before the modernization. The dry air blowing system was also improved and the internal volume of the amplifier was additionally divided into sections, which contributed to more stable operation.

Laser stabilization electronics development. Next, we began developing electronics to stabilize the parameters of the seed laser. Taking into account structured gain spectrum shape of the Ho:YAG active medium, which is used in our writing setup we estimate significant influence of the seed laser spectrum central wavelength drift on the amplified pulse spectral width and as a result – compressed pulse duration [1]. For this purpose, we started works on electronics development for the seed laser central wavelength stabilization.

The starting point in the development of electronics is the fact that the seed laser provides the ability to tune the central wavelength in the spectrum of the output pulses and the control element is a piezoceramic translator. In this case, the wavelength can also be controlled by measuring the pulse repetition rate in the radio frequency range, which is very convenient for building an electronic control system. Directly in the laser, the wavelength adjustment is implemented without feedback, which means that it is not absolutely precise, i.e., having set the voltage on the piezo translator at one point in time, after a certain time interval, the wavelength of the laser radiation will already be different, primarily due to the temperature drift of the mechanical parts of the laser. Thus, it is necessary to develop an electronic circuit that will monitor the pulse repetition rate and, in accordance with the deviation of the latter, provide a control voltage for the piezo translator. For this purpose, a block diagram of the stabilization system was suggested (see Fig. 1).

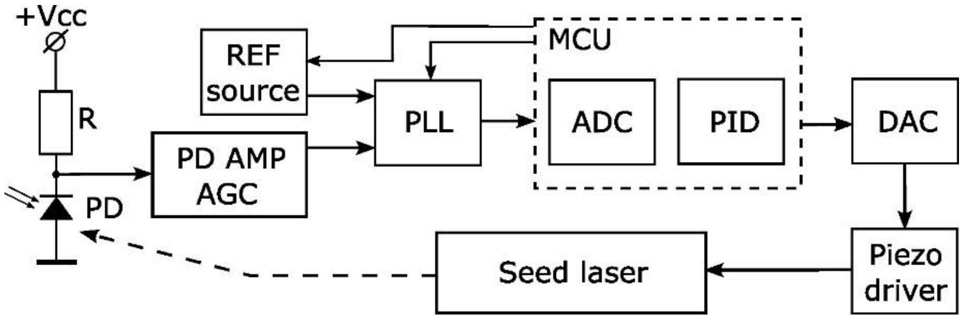

Fig. 1. Block diagram of the seed laser stabilization system.

To stabilize the laser parameters, a PLL-based circuit is used. The signal from the photodetector PD goes to an amplifier PD AMP with an automatic gain control function (AGC), where it is amplified to the desired amplitude, sufficient for perception by the PLL block. Then the signal goes to the PLL block, where it is compared with the reference frequency signal received from the reference generator block (REF source). As a result of the comparison, an error signal is formed, which, passing through the PLL loop filters, goes to the ADC of the microcontroller (MCU). The microcontroller performs digital signal processing, including filtering and a proportional-integral-derivative controller (PID). Then the digital control signal received from the PID controller program is fed to the DAC, amplified to the required level and then fed to the piezo translator installed directly in the laser. By changing the voltage on the piezo translator, it is possible to regulate the pulse repetition rate of the laser, and part of the laser output power is fed to the feedback photodetector, which ensures the operation of the described system.

Conclusion. As of now, output power/energy stability of the regenerative amplifier is significantly improved. Regarding electronics development, the photodiode signal and piezo driver amplifier units, as well as the PLL unit, have been developed, manufactured and tested. Work is underway on the remaining units of the system including Microcontroller unit, Reference frequency unit, DAC unit, Power supply as well as assembly of all units into a finished product and adjustment of its operation. We anticipate a significant reduction in defect sizes to sub-1 µm as a result of the successful launch of the developed electronic system for stabilizing the parameters of the seed laser.

References

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