Semi-automatic system with 4 mirrors for high-power laser beam alignment

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***Abstract* — Laser beam alignment requires the work with an open beam (‘life’) and involves directing the beam towards a series of reflective or partially reflective surfaces, such as mirrors or lenses, so that the beam follows some predetermined path. The system is proposed for the alignment purposes of the beamlines and Secondary Sources driven by the high-power laser system. The beam of the diode laser (‘pilot’) with certain precision reproduces the major parameters of the main beam - in particular, central wavelength, wavefront curvature (beam sphericity), beam diameter, pointing, etc. The alignment laser diode beam is inserted at the position between the last amplifier stage and the beam transport entrance of the high-power laser system. In general, the laser beam should be propagated to target area on the distance > 40 m, therefore such a system should provide highest accuracy of the beam matching. Alignment operations are required to constrain the beam within the optical clear aperture of mirrors and lenses. The dynamic alignment involves a semi-automatic system driving motorized equipment (mirrors and linear stages), in order to align the beam.**

Keywords* — *beam alignment, high-power laser setups, ultrahigh pulse laser radiation, automatization of processes

I. Introduction

With the development of laser physics, the number of powerful laser radiation sources is growing. At the moment, there are a number of already operating petawatt-level setups (for example, Nova [1], Shenguang III [2], PEARL [3], DRACO [3], LMJ [4], LFEX [5]), as well as some complexes are under construction (for example, ELI-ALPS [4], ATLAS [4], ZEUS [6], Apollon [4]). All these projects are designed for fundamental research of processes in the atomic nucleus, vacuum physics, modeling of atomic interactions, laboratory astrophysics, particle acceleration, studying the mechanisms of interaction of laser radiation with matter, and studying the properties of high-temperature plasma.

At present, when solving the alignment of high-power pulsed laser systems, the so-called reference approach is used, i.e., beam deviation occurs in real time with simultaneous analysis of the beam position both in the near- and far-field. The parameters of the “live” laser are taken as reference and after that, with the help of motorized optomechanical devices, a gradual decrease in the deviation of the main and secondary beams occurs.

However, there are some shortcomings of state-of-the-art optical alignment setups: ignoring the wavefront curvature [2][7] and sensitivity to mechanical parts performance degradation over time [[4],[5].

We propose to use the alignment optical setup with near-, far-field monitoring system for analyzing the beam positioning, diameter and wavefront sensor for analyzing the wavefront curvature. The automatic alignment is performed using the gimbal mounts.

II. System parameters

As usual, 4 main parameters define the quality of the alignment system to provide correspondence of the ‘life’ and ‘pilot’ beams with high accuracy in target room:

- pointing accuracy;
- positioning accuracy;
- beam size matching;
- wavefront curvature.

The ‘pilot’ beam positioning and the beam size matching accuracy with the ‘life’ beam is measured using the near-field monitoring camera. The pointing accuracy of the beams could be analyzed using the far-field camera. And wavefront curvature is analyzed by Shack-Hartmann wavefront sensor.

III. Optical setup design

The proposing alignment optical setup includes main components:

- Fiber-coupled diode laser with parameters identical with ‘life’ beam: used as a pilot laser for combining the beamline of the operational laser beam.
- Pilot beam line system: used for alignment of the pilot laser.
- Far- and near-field monitoring system: used for monitoring of focal spot position, size, intensity distribution, wavefront aberrations (tip-tilt, defocus) of the ‘life’ and ‘pilot’ beams.
- Steering mirrors: used for overlapping the ‘life’ and ‘pilot’ beams.
- Breadboards: used for placing of main components of the alignment system.

It could be divided on two main arms: pilot beam system and monitoring system (Fig. 1).

IV. Algorithm of alignment

The algorithm of the alignment could be divided on 4 steps:

- Step 1. Measurement of the ‘life’ beam and applying of its parameters as the reference.
- Step 2. Steering mirror (3) provides the overlap of the beam center of ‘pilot’ to reference

parameters on near-field camera using the stepper motors. After achieving necessary accuracy algorithm starts to coincide beams in the far-field.

- Step 3. Steering mirror (4) the overlap of the beam center of 'pilot' to reference parameters on far-field camera using the stepper motors. After achieving necessary accuracy algorithm returns to reduction the deviation of beams in the near-field.

performance was proved using the two diode laser beams. The deviations of the main alignment parameters from 'live' to 'pilot' beam are following: positioning accuracy (X axis – 0.96 µm, Y axis – 0.96 µm), pointing accuracy (X axis – 8.78 µm, Y axis – 6.14 µm), beam size matching (X axis – 0.96 µm, Y axis – 0.96 µm), wavefront curvature (P-V = -0.072 µm).

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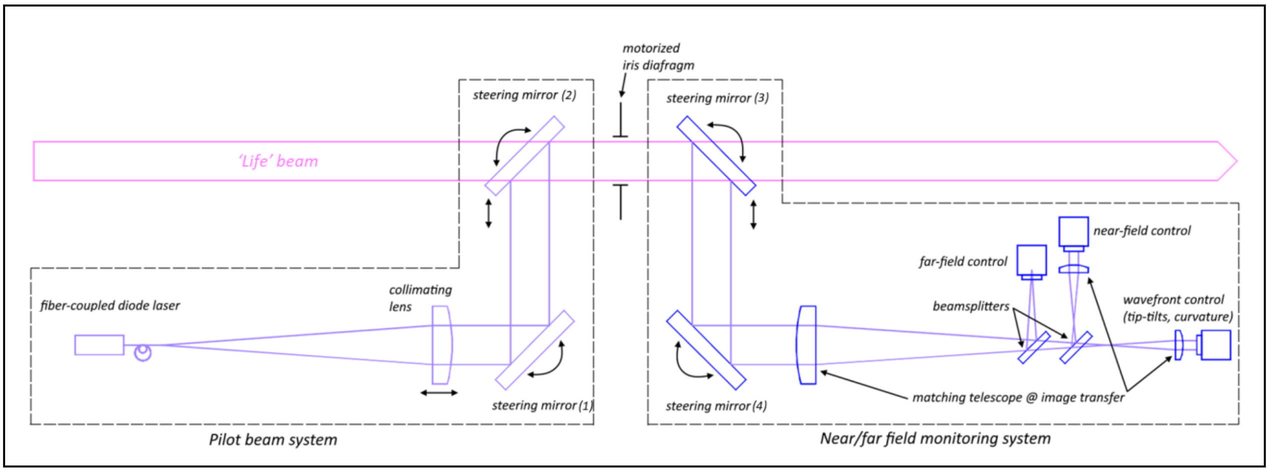

Fig. 1. Principal scheme of the alignment system

- Step 4. Repetition of steps 2 and 3 since achieving the necessary accuracy simultaneously on near- and far-field monitoring cameras.
- Step 5. Compensation of overall wavefront curvature by analyzing the defocus on Shack-Hartmann sensor and shifting the laser diode on translation stage.

V. PERFORMANCE OF THE SYSTEM

To prove the performance of the system two diode lasers were used. The values of the main parameters are following:

- positioning accuracy: deviation on X axis – 0.96 µm, on Y axis – 0.96 µm;
- pointing accuracy: deviation on X axis – 8.78 µm, on Y axis – 6.14 µm;
- beam size matching: deviation on X axis – 0.96 µm, on Y axis – 0.96 µm;
- wavefront curvature: -0.072 µm (P-V).

VI. CONCLUSION

We proposed the semi-automatic alignment system for overlapping the beams in the high-power ultrashort pulse laser setups. The optical setup contains the diode laser as a secondary source with parameters (wavelength, intensity distribution etc.) identical to main beam, 4 steering mirrors to provide coincidence of the 'life' and 'pilot' beams, far- and near-field monitoring system for analyzing of focal spot position, size, intensity distribution, wavefront aberrations (tip-tilt, defocus) of the 'life' and 'pilot' beams. The system

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