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STRATEGY OF METAHEURISTIC ALGORITHMS FOR LASER OPTIMIZATION

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A laser is one of the most important experimnetal tool. In synchrotoron radiation field, a laser widely used for experiments with Pump-Probe techniques and so on. Especially for the future X-ray-FELs, a laser has important roles as a seed light sourecs, or photocathode-illuminating light souce to generate a high brightness electron bunch. The controls of laser pulse characteristics are required for many kinds of experiments. A laser pulse is characterized in its pulse energy, pulse chirp, spectral distributions (both of intensity and phase), 3D-profile (both of spatial and temporal), wavefront distortion, M^2-value, pointing stability, timing jitter, *etc*. However, the laser should be tuned and customized for each requirement by laser experts. The automatic tuning of laser is required to realize with some sophisticated algorithms. The metaheuristic algorithm is one of the useful candidates to find one of the best solutions as acceptable as possible. The metaheuristic laser tuning system is expected to save our human resources and time for the laser preparations.

However, these laser pulse characteristics are not perfectly independent of each other. In this case, it is almost impossible to determine the best solution uniquely by mathematical formulae. The metaheuristic algorithm is powerful methodology to find some of the acceptable and the most preferable solutions with searching better parameters. Many kinds of metaheuristic algorithms have been proposed and applied widely. I utilised a genetic algorithm (GA) [1] and a simulated annealing method [2] to optimize 3D laser pulse shape, and a hill climing methode with a fuzzy set theory [3] to align a laser to reliable path for each experiment at advanced photoinjector test facility in SPring-8. Applying any kind of metaheuristic algorithm, a great number of system's parameter must be introduced. Making the probability higher to find some solutions as good as possible, it is necessary to increase freedom of its searching space. For instance, optimizing laser shape, I introduced adaptive optics to increase the parameters of laser system. I have planned to use a deformable mirror (DM) [1] for spatial (transverse) shaping, and a glass (fused silica)- plate-based spatial light modulator (SLM) [4] for temporal (longitudinal) shaping). In 2005, I completed system to manipulate 3D laser pulse shape as an illuminating light source for a photocathode RF gun [5]. The laser spatial profile was adaptively optimized with a metaheuristic method designed for a DM that consists of an aluminium-coated membrane and 59 small mirror actuators behind the reflective membrane. Adjusting voltages between the control electrodes on the boundary actuators results in fine adjustment of each mirror actuator; the adjustable region of the control voltages is between 0 and 250 V in steps of 1 V, making it possible to shape the arbitrary spatial profiles for a total of 250^{59} ($\sim 10^{141}$) deforming possibilities. Because of such high adjustability, the spatial shaping with the DM needs a sophisticated algorithm. Software based on a GA was developed to adaptively optimize DM deformation.

The set of the voltages of all DM-electrodes is treated as chromosomes in this software. A closed loop system is essential for a DM to adaptively optimize the laser's spatial profile. I used a PC to control the electrode voltage of the DM and to measure the spatial profile with a laser profile monitor (LBA300-PC, Spiricon Inc.). Laser light is reflected with deformation by the DM and monitored with the laser profile monitor, whose analyzing program can provide many parameters to evaluate the beam profile characteristics. I chose useful parameters to evaluate the flattop profiles and made a fitting function for the developed the GA software to optimize the profile toward an ideal flattop. The fitting function is a linear combination of flattop shaping parameters with certain optimal weights for fast convergence. The fitting function is returned as feedback to control the DM with the GA. As a result, the laser profile on the cathode surface was spatially shaped as a quasi-flattop profile [2].

I review mainly adaptive optical system developed with metaheuristic algorithms for controlling 3D laser pulse shape and laser alignment.

References

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