CLAIMS

1. A laser-processing apparatus, comprising:

a laser source operative to generate a beam of laser energy, wherein the beam of laser energy is propagatable along a beam path;

an acousto-optic deflector (AOD) system having at least one AOD crystal arranged within the beam path, wherein the AOD is operative to diffract the beam of laser energy;

a controller coupled to the laser source and the AOD system,

wherein the controller is configured to control operation of the AOD system,

wherein the controller is configured to output one or more AOD control commands to the AOD system and one or more laser control commands to the laser source;

a control loop operative to adjust a timing offset between a first AOD control command output to the laser source and a first laser control command output to the RF source; and

a beam analysis system operative to measure one or more characteristics of the beam of laser energy, generate measurement data representative of one or more of the measured beam characteristics, and transmit the measurement data to the controller,

wherein the one or more measured laser characteristics is a laser spot position;

wherein the beam analysis system is configured to:

measure the laser spot position and generate measurement data representative of the laser spot position;

output the measurement data to the controller,

wherein the controller is operative to:

develop a correlation between the laser spot position and the timing offset based on the data representative of the laser spot position;

create an adjusted timing offset based on the correlation between the laser spot position and the timing offset;

output a second AOD control command to the AOD system based on the adjusted timing offset; and

output a second laser control command to the laser source based on the adjusted timing offset.

2. The laser-processing apparatus of claim 1, wherein the AOD includes first AOD and a second AOD operative to diffract the beam path in a first direction and a second direction, respectively.

3. The laser processing apparatus of claim 2, wherein the second AOD control command results in a chirped acoustic signal propagating through at least one AOD crystal of at least one of the first AOD and the second AOD.

4. The laser processing apparatus of claim 3, wherein the second laser control command results in the beam of laser energy overlapping the chirped acoustic signal.

5. The laser-processing apparatus of claim 1, wherein the beam analysis system includes at least one of a camera-based beam profiler, a Rayleigh-scattering beam profiler, and a rotating slit beam profiler.

6. A method of controlling laser beam characteristics, comprising:

generating a beam of laser energy;

directing, using an AOD, the beam of laser energy along a beam path to a beam analysis system;

using the beam analysis system:

measuring, using the beam analysis system, one or more characteristics of the beam of laser energy;

generating measurement data representative of one or more of the measured beam characteristics;

wherein the one or more beam characteristics is a laser spot position;

transmitting the measurement data representative of the laser spot position from the beam analysis system to a controller; and

providing a control loop operative to adjust a timing offset between a first AOD control command and a first laser control command;

using the controller:

developing a correlation between the laser spot position and the timing offset based on the data representative of the laser spot position;

creating an adjusted timing offset based on the correlation between the laser spot position and the timing offset;

outputting a second AOD control command to the at least one AOD system based on the adjusted timing offset; and

outputting a second laser control command based on the adjusted timing offset to the laser source.

7. A method of controlling laser beam characteristics, comprising:

generating a beam of laser energy;

directing, using at least one selected from the group consisting of a first AOD and a second AOD, the beam of laser energy along a beam path to a beam analysis system;

measuring, using the beam analysis system, one or more characteristics of the beam of laser energy;

generating measurement data representative of one or more of the measured beam characteristics;

transmitting the measurement data from the beam analysis system to a controller; and

outputting control commands from the controller to at least one of the first AOD and the second AOD based, at least in part, on the measurement data,

wherein the control commands based on the measurement data, output to the second AOD from the controller, are operative to correct a beam astigmatism caused by the first AOD.

8. A method, comprising:

during a measurement step:

generating a plurality of laser pulses based on a control command sent to a laser source from a controller;

generating an acoustic signal within an AOD, based on an AOD control command sent to the AOD from the controller, wherein the acoustic signal is configured to diffract at least one laser pulse of the plurality of laser pulses;

measuring at least one characteristic of the plurality of diffracted laser pulses, wherein, during the measuring, adjusting a timing offset between the control command and the AOD control command;

generating measurement data representative of the at least one measured characteristic for each diffracted laser pulse; and

correlating at least one measurement datum of the measurement data with the timing offset associated with each diffracted laser pulse;

during a workpiece-processing step:

generating a laser pulse;

generating an acoustic signal within an AOD, wherein the acoustic signal is configured to diffract at least one laser pulse of the plurality of laser pulses; and

directing the at least one diffracted laser pulse to a workpiece,

wherein the timing offset between the laser control command and the AOD control command corresponds to a timing offset that was correlated with the measurement data in the measurement step that has a predetermined relationship with a reference characteristic.

9. The method of claim 8, wherein the acoustic signal is a chirped acoustic signal.

10. The method of claim 8, wherein the acoustic signal is a non-chirped acoustic signal.

11. The method of claim 8, wherein the characteristic of the plurality of diffracted laser pulses is at least one of pulse repetition rate, beam diameter, spot size, circularity, astigmatism, focus height, beam waist, or beam axis position.

12. A method, comprising:

during a measurement step:

generating a beam of laser energy;

generating an acoustic signal within an AOD, wherein the acoustic signal is configured to diffract the beam of laser energy;

measuring at least one characteristic of the diffracted beam of laser energy;

generating measurement data representative of the at least one measured characteristic for the diffracted beam of laser energy;

correlating at least one measurement datum of the measurement data with a reference value of one or more system operating parameters associated with the diffracted beam of laser energy;

during a workpiece-processing step:

generating an acoustic signal within the AOD, wherein the acoustic signal is configured to diffract the beam of laser energy; and

directing the beam of laser energy to a workpiece,

wherein the characteristic of the beam of laser energy corresponds to a reference value of the at least one of the system operating parameters that was correlated with the measurement data in the measurement step that has a predetermined relationship with the characteristic of the beam of laser energy.

13. The method of claim 12, wherein the characteristic of the beam of laser energy is at least one of pulse repetition rate, beam diameter, spot size, circularity, astigmatism, focus height, beam waist, or beam axis position.

14. The method of claim 12, wherein the system operating parameter is at least one of RF signal chirp rate, acoustic signal chirp rate, and pulse repetition rate.

15. A method for correcting for laser beam astigmatism, comprising:

generating a beam of laser energy;

directing, using a first AOD, the beam of laser energy along a beam path to a beam analysis system;

measuring, using the beam analysis system, a beam astigmatism of the beam of laser energy;

generating, using the beam analysis system, measurement data representative of the measured beam astigmatism of the beam of laser energy;

transmitting the measurement data to a controller; and

outputting control commands from the controller to a second AOD, the control commands operative to operate the second AOD to correct for the measured beam astigmatism.

16. The method of claim 15, wherein the second AOD applies a single axis focusing term to the beam of laser energy to correct for the measured beam astigmatism.