CLAIMS

1. A method for controlling a multi-axis machine tool configured to process a workpiece using a tool, the multi-axis machine tool comprising a rotary actuator configured to impart relative movement between the tool and the workpiece about a first axis, a first linear actuator configured to impart relative movement between the tool and the workpiece along a second axis, a second linear actuator configured to impart relative movement between the tool and the workpiece along a third axis, and a third linear actuator configured to impart relative movement between the tool and the workpiece along at least one selected from the group consisting of the second axis and the third axis, wherein the third linear actuator is configured to impart relative movement between the tool and the workpiece at a bandwidth that is higher than a bandwidth with which relative movement between the tool and the workpiece can be imparted by the first linear actuator or the second linear actuator, the method comprising:

receiving a preliminary rotary actuator command, the preliminary rotary actuator command having frequency content exceeding a bandwidth of the rotary actuator;

generating a processed rotary actuator command based, at least in part, on the preliminary rotary actuator command, the processed rotary actuator command having frequency content within a bandwidth of the rotary actuator;

generating a first linear actuator command, a second linear actuator command and a third linear actuator command based, at least in part, on the processed rotary actuator command;

outputting the processed rotary actuator command to the rotary actuator;

outputting the first linear actuator command to the first linear actuator;

outputting the second linear actuator command to the second linear actuator; and

outputting the third linear actuator command to the third linear actuator.

2. The method of claim 1, wherein the second axis is orthogonal to the first axis.

3. The method of claim 1, wherein generating the processed rotary actuator command comprises filtering the preliminary rotary actuator command.

4. The method of claim 1, wherein generating the first linear actuator command and the second linear actuator command comprises:

generating a set of intermediate linear actuator commands based on the preliminary rotary actuator command and at least one preliminary linear actuator command; and

processing the set of intermediate linear actuator commands based, at least in part, on the processed rotary actuator command.

5. The method of claim 1, further comprising processing the workpiece with the tool while imparting relative movement about the first axis.

6. The method of claim 5, wherein processing the workpiece with the tool comprises directing laser light to the workpiece.

7. A controller for controlling a multi-axis machine tool configured to process a workpiece using a tool, the multi-axis machine tool comprising a rotary actuator configured to impart relative movement between the tool and the workpiece about a first axis, a first linear actuator responsive to a first linear actuator command to impart relative movement between the tool and the workpiece along a second axis, a second linear actuator responsive to a second linear actuator command to impart relative movement between the tool and the workpiece along a third axis, and a third linear actuator responsive to a third linear actuator command to impart relative movement between the tool and the workpiece along at least one selected from the group consisting of the second axis and the third axis, wherein the third linear actuator is configured to impart relative movement between the tool and the workpiece at a bandwidth that is higher than a bandwidth with which relative movement between the tool and the workpiece can be imparted by the first linear actuator or the second linear actuator, the controller comprising:

at least one processor and computer memory accessible to the at least one processor, the computer memory having instructions stored thereon which, when executed by the at least one processor, cause the controller to:

generate a processed rotary actuator command based, at least in part, on a preliminary rotary actuator command having frequency content exceeding a bandwidth of the

rotary actuator, the processed rotary actuator command having frequency content within a bandwidth of the rotary actuator;

generate the first linear actuator command, the second linear actuator command and the third linear actuator command based, at least in part, on the processed rotary actuator command;

output the processed rotary actuator command, the first linear actuator command, the second linear actuator command and the third linear actuator command.

8. A multi-axis machine tool, comprising:

a tool configured to process a workpiece;

a first rotary actuator configured to impart relative movement between the tool and the workpiece about a rotary axis extending along a first axis;

a first linear actuator configured to impart relative movement between the tool and the workpiece along a linear axis extending along a second axis;

a second linear actuator configured to impart relative movement between the tool and the workpiece along a linear axis extending along a third axis;

a third linear actuator configured to impart relative movement between the tool and the workpiece along at least one selected from the group consisting of the first axis, the second axis and the third axis, wherein the third linear actuator is configured to impart relative movement between the tool and the workpiece at a bandwidth that is higher than a bandwidth with which relative movement between the tool and the workpiece can be imparted by the first linear actuator or the second linear actuator; and

a controller operatively coupled to the first rotary actuator, the first linear actuator and the second linear actuator, the controller configured to:

generate a processed rotary actuator command based, at least in part, on a preliminary rotary actuator command having frequency content exceeding a bandwidth of the first rotary actuator, the processed rotary actuator command having frequency content within a bandwidth of the first rotary actuator;

generate a first linear actuator command and a second linear actuator command based, at least in part, on the processed rotary actuator command;

output the processed rotary actuator command to the first rotary actuator;

output the first linear actuator command to the first linear actuator; and

output the second linear actuator command to the second linear actuator.

9. The multi-axis machine tool of claim 8, further comprising a second rotary actuator configured to impart relative movement between the tool and the workpiece about the first axis, wherein a bandwidth of the second rotary actuator is higher than a bandwidth of the first rotary actuator.

10. The multi-axis machine tool of claim 8, further comprising a laser source and the tool includes a focused beam of laser light.

11. The multi-axis machine tool of claim 8, wherein the tool includes a waterjet.

12. The multi-axis machine tool of claim 8, wherein the third linear actuator includes a mirror.

13. The multi-axis machine tool of claim 8, wherein the third linear actuator includes a lens.

14. The multi-axis machine tool of claim 8, wherein the third linear actuator includes an acousto-optic deflector (AOD) system.

15. The multi-axis machine tool of claim 8, wherein the third linear actuator is further configured to impart relative movement between the tool and the workpiece along the first axis.

~~16. A multi-axis machine tool, comprising:~~

~~a laser source configured to generate a beam of laser light;~~

~~a tool tip positioning assembly, wherein the tool tip positioning assembly includes a scan lens , a linear actuator , and an acousto-optic deflector (AOD) system , wherein the scan lens is~~

arranged and configured to focus the beam of laser light to thereby produce a focused beam of laser light that propagates along a beam axis and has a beam waist , wherein the linear actuator is coupled to the scan lens and is operative to move the scan lens along the beam axis , and wherein the AOD system is operative to move the beam waist of the beam of laser light along the beam axis;

a workpiece positioning assembly configured to move and position the workpiece such that the workpiece intersects the beam axis;

a controller operatively coupled to the laser source, the workpiece positioning assembly, and the tool tip positioning assembly and configured to control an operation of the laser source, the workpiece positioning assembly, and the tool tip positioning assembly,

wherein, in controlling the operation of the tool tip positioning assembly, the controller is operative to:

generate a low-frequency linear actuator command and a high-frequency linear actuator command based, at least in part, on an input linear actuator command, a first output linear output command and a second output linear output command , wherein the low-frequency linear actuator command has a frequency content that is within the bandwidth of the linear actuator, and wherein the high-frequency linear actuator command has a frequency content that is within the bandwidth of the AOD system at least one positioner;

output the low-frequency content linear actuator command to the linear actuator; and

output the high-frequency content linear actuator command to the AOD system at least one positioner.

17. The multi-axis machine tool of claim 16, wherein the tool tip positioning assembly is operative to translate the beam waist along at least one axis.

18. The multi-axis machine tool of claim 16, wherein the tool tip positioning assembly is operative to rotate the beam waist about at least one axis.

19. The multi-axis machine tool of claim 16, wherein the AOD system includes:

a first AOD system operative to diffract the beam of laser light along a first axis; and

~~a second AOD system operative to diffract the beam of laser light along a second axis orthogonal to the first axis.~~

~~20. The multi-axis machine tool of claim 19, wherein the controller is further configured to control operations of the first AOD system and the second AOD system to translate the beam waist along the path.~~

~~21. The multi-axis machine tool of claim 19, wherein the controller is further configured to control operations of at least one selected from the group of the first AOD system and the second AOD system to translate the beam waist along an axis that is transverse to the path.~~