CLAIMS

1. A mode-locked laser comprising:

at least one laser diode; and

at least one laser cavity containing at least one gain medium;

wherein the output of the laser is configured to produce a train of laser pulses having a modulated amplitude.

2. The mode-locked laser of claim 1, wherein the amplitude of the laser pulses in the laser pulse train modulates substantially periodically, resulting in a periodically modulated laser pulse train.

3. The mode-locked laser of claim 2,

wherein one or more parameters of the periodically modulated laser pulse train are selected to achieve either or both of:

improvement in a fluorescence yield of one or more dyes to which the laser pulse train is applied; or

improvement of the saturation characteristics of the dye, thereby increasing the longevity of the dye and reducing the generation of host species such as free radicals that can affect target molecules;

wherein the one or more parameters include peak amplitude, modulation shape, repetition rate of pulses in the laser pulse train, laser wavelength, photon energy in the light emitted by the laser, pulse duty cycle, pulse width, and modulation duty cycle.

4. The mode-locked laser of claim 3, wherein the modulation shape is chosen from a set of shapes including a square, triangle, sinusoid, and an arbitrary shape with varying pulse rise times, pulse fall times, and pulse duty cycles.

5. The mode-locked laser of any one of claims 1-4, wherein the modulation of the laser pulse amplitude is produced by modulation of a current applied to the laser diode.

6. The mode-locked laser of any one of claims 1-4, further including:

i) an acousto-optic modulator external to the laser cavity that produces at least in part the modulation of the laser pulse~~.~~;

~~7. The mode-locked laser of any one of claims 1-4, further including~~ ii) an electro-optic modulator external to the laser cavity that produces at least in part the modulation of the laser pulse~~.~~;

~~8. The mode-locked laser of any one of claims 1-4, further including~~ iii) a mechanical optical chopper external to the laser cavity that produces at least in part the modulation of the laser pulse~~.~~;

~~9. The mode-locked laser of any one of claims 1-4, further including~~ iv) a pulse picker external to the laser cavity that produces at least in part the modulation of the laser pulse~~.~~;

~~10. The mode-locked laser of any one of claims 1-4, further including~~ v) an acousto-optic modulator inside the laser cavity that produces at least in part the modulation of the pulse~~.~~;

~~11. The mode-locked laser of any one of claims 1-4, further including~~ vi) an electro-optic modulator inside the laser cavity that produces at least in part the modulation of the pulse~~.~~;

~~12. The mode-locked laser of any one of claims 1-4, further including~~ vii) a mechanical optical chopper inside the laser cavity that produces at least in part the modulation of the pulse~~.~~; or

~~13. The mode-locked laser of any one of claims 1-4, further including~~ viii) a pulse picker inside the laser cavity that produces at least in part the modulation of the pulse.

~~14~~7. The mode-locked laser of any one of claims 1-~~13~~6, wherein the gain crystal comprises a material selected from the list of: neodymium vanadate (Nd3+:YVO4); a vanadate; and a host material.

~~15~~8. The mode-locked laser of any one of claims 1-~~14~~7, further comprising a saturable absorber mirror mounted on a plate at an end of the laser cavity, wherein the plate is configured to be adjusted with only two degrees of freedom which do not include angle adjustments with respect to an optical axis of an intracavity beam of the laser cavity that is incident on the saturable absorber mirror.

~~16~~9. The mode-locked laser of any one of claims 1-~~15~~8, wherein a first beam waist of an intracavity beam within a gain medium is between 100 microns and 150 microns and a second beam waist of the intracavity beam at a saturable absorber is between 75 microns and 125 microns.

~~17~~10. The mode-locked laser of any one of claims 1-~~16~~9, further comprising:

a first focusing optic located within the laser cavity; and

a laser window or optical flat located within the laser cavity, wherein the first focusing optic and laser window or optical flat are arranged to adjust an incident angle of an intracavity beam on a saturable absorber mirror by rotating the laser window or optical flat.

~~18~~11. The mode-locked laser of any one of claims ~~15~~8-~~17~~10, further comprising a cavity length extending region located within the laser cavity between the gain medium and the saturable absorber mirror, wherein the cavity length extending region folds the intracavity beam at least four times.

~~19~~12. The mode-locked laser of claim ~~18~~11, wherein the cavity length extending region comprises:

a first reflector; and

a second focusing reflector located between the saturable absorber mirror and the gain medium, wherein the first reflector and the second focusing reflector fold the intracavity beam three times on successive reflections~~.~~

~~20. The mode-locked laser of any one of claims 18-19,~~; and/or wherein the cavity length extending region comprises a first reflector that folds the intracavity beam multiple times.

~~21~~13. The mode-locked laser of any one of claims 1-~~14~~7, further comprising:

an output coupler located at a first end of the laser cavity;

a saturable absorber mirror located at a second end of the laser cavity;

a first focusing optic located within the laser cavity between the gain medium and the saturable absorber mirror; and

a second focusing optic located within the laser cavity between the first focusing optic and the saturable absorber mirror.

~~22~~14. The mode-locked laser of claim ~~21~~13, wherein an intracavity beam between the first focusing optic and the second focusing optic is essentially collimated~~.~~

~~23. The mode-locked laser of claim 21,~~ or wherein a focal length of the first focusing optic is between 240 mm and 260 mm and a focal length of the second focusing optic is between 240 mm and 260 mm~~.~~

~~24. The mode-locked laser of claim 23,~~, optionally wherein the output coupler is located between 280 mm and 300 mm from the first focusing optic and the gain medium is located between 4 mm and 8 mm from the output coupler.

~~25~~15. The mode-locked laser of any one of claims 1-~~24~~14, further comprising only one mirror located within the laser cavity that provides angular adjustment of the one mirror while the mode-locked laser is operating~~.~~

~~26. The mode-locked laser of any one of claims 1-25, further comprising~~, and/or a frequency-doubling crystal mounted on the chassis and arranged to double a frequency of an output beam from the laser cavity.

~~38~~16. The mode-locked laser of any one of claims 1-~~26~~15, wherein the laser pulses are used to excite a fluorescent dye of a single molecule or a small number of molecules.

~~27~~17. A computer-readable medium storing instructions that, when executed by a processor, cause the processor to control a mode-locked laser, wherein the laser comprises:

at least one laser diode;

at least one laser cavity containing at least one gain medium;

at least one reflector; and

at least one out output coupler located at a first end of the laser cavity; and wherein the instructions cause the computer to cause the laser to produce a train of laser pulses having a modulated amplitude, wherein the amplitude of the laser pulses in the laser pulse train modulates substantially periodically, resulting in a periodically modulated laser pulse train.

~~28~~18. The computer-readable medium storing instructions of claim ~~27~~17, wherein the instructions, when executed, further cause the processor to:

control the amount of current applied to the laser diode; and

cause the modulation in the amplitude of the power of the laser pulses by modulating the amount of current applied to the laser diode.

~~29~~19. The computer-readable medium storing instructions of any one of claims ~~27~~17-~~28~~18, wherein the instructions, when executed, further cause the processor to:

adjust the parameters of the laser pulse train to improve the fluorescence yield of one or more dyes to which the laser pulse train is applied.

~~30~~20. The computer-readable medium storing instructions of any one of claims ~~27~~17-~~29~~19, wherein the laser pulse train parameters include peak amplitude, modulation shape, repetition rate of pulses in the laser pulse train, laser wavelength, photon energy in the light emitted by the laser, pulse duty cycle, pulse width, and modulation duty cycle.

~~31~~21. The computer-readable medium storing instructions of any one of claims ~~27~~17-~~30~~20, wherein the modulation shape is chosen from a set of shapes including a square, triangle, sinusoid, and an arbitrary shape with varying pulse rise times, pulse fall times, and pulse duty cycles.

~~32~~22. The computer-readable medium storing instructions of any one of claims ~~27~~17-~~31~~21, wherein the instructions, when executed, further cause the processor to:

receive an input indicating a material or combination of materials to which the laser pulse train is to be applied; and

adjust the parameters of the laser pulse train to optimize the fluorescence of the indicated material or combination of materials when the pulse train is applied.

~~39~~23. The computer-readable medium storing instructions of claim ~~27~~17, wherein the instructions, when executed, further cause the processor to cause the laser to excite a fluorescent dye of a single molecule or a small number of molecules.

~~33~~24. A method of operating a mode-locked laser, the laser comprising:

at least one laser diode;

at least one laser cavity containing at least one gain medium;

at least one reflector; and

at least one out output coupler located at a first end of the laser cavity;

the method comprising:

producing a train of laser pulses whose amplitudes modulate substantially periodically; and

applying the train of laser pulses to a fluorescent dye or combination of fluorescent dyes.

~~34~~25. The method of claim ~~33~~24, wherein the modulation of the amplitude of the laser pulses is accomplished by varying the current applied to the laser diode.

~~35~~26. The method of any one of claims ~~33~~24-~~34~~25, wherein the laser pulse train parameters include peak amplitude, modulation shape, repetition rate of pulses in the laser pulse train, laser wavelength, photon energy in the light emitted by the laser, pulse duty cycle, pulse width, and modulation duty cycle~~.~~

~~36. The method of any one of claims 33-35,~~ , and/or wherein the modulation shape is chosen from a set of shapes including a square, triangle, sinusoid, and an arbitrary shape with varying pulse rise times, pulse fall times, and pulse duty cycles.

~~37~~27. The method of any one of claims ~~33~~24-~~36~~26, further comprising:

receiving an indication of the dye or combination of dyes to which the laser pulse train is to be applied; and

adjusting the parameters of the laser pulse train based on the received indication to optimize the fluorescence of the indicated material or combination of materials to which the pulse train is applied.

~~38. The mode-locked laser of any one of claims 1-26, wherein the laser pulses are used to excite a fluorescent dye of a single molecule or a small number of molecules.~~

~~39. The computer-readable medium storing instructions of claim 27, wherein the instructions, when executed, further cause the processor to cause the laser to excite a fluorescent dye of a single molecule or a small number of molecules.~~

~~40~~28. The method of any one of claims ~~33~~24-~~36~~26, further comprising:

using the laser pulse train to excite a fluorescent dye of a single molecule or a small number of molecules~~.~~

~~41. The method of any one of claims 33-36, further comprising~~ ; or selecting parameters of the laser pulse train to improve of the saturation characteristics of the dye, thereby increasing the longevity of the dye and reducing the generation of host species such as free radicals that can affect target molecules.

~~42. A gain-switched laser comprising:~~

~~at least one laser cavity containing at least one gain medium;~~

~~wherein the output of the laser is configured to produce a train of interleaved laser pulses of different color excitation.~~

~~43. The gain-switched laser of claim 42, further including an optical modulator external to the laser cavity that produces at least in part the modulation of the laser pulse, wherein the optical modulator is chosen from the set of: optical chopper, electro-optic modulator, accousto-optic modulator.~~

~~44. The gain-switched laser of claim 42, further comprising one or more diodes that produce gain-switched laser pulses to excite the gain medium.~~

~~45. The gain-switched laser of claim 44, wherein the modulation is produced by one or more electrical signals that introduce one or more additional modulating signals along with the one or more current pulses that produce the gain-switched laser pulses from the one or more diodes.~~

~~46. A method of using the gain-switched laser of any of claims 42-45, comprising the steps of:~~

~~applying the laser pulse train to a fluorescent dye; and~~

~~identifying the dye by examining the relative absorption of the dye at the different color excitations of the pulses in the laser pulse train.~~

~~47. The method of claim 46, wherein the quantity of dye is in the range of a single molecule to a small number of molecules.~~

~~48. The gain-switched laser of any one of claims 44-45, wherein the clock phases for the one or more current pulses that produce the gain switched laser pulses from the one or more diodes are independent and directly controlled.~~

~~49. A method of using the gain-switched laser of claim 48, comprising the steps of:~~

~~applying the laser pulse train to a fluorescent dye;~~

~~detecting photons produced by the fluorescence of the dye using a photon detector array; and~~

~~using the clock phases for the one or more current pulses to configure the detector array to account for skew and propagation time.~~

~~50. The method of claim 49, wherein the photon detector array is large.~~

~~51. The method of any of one of claims 49-50, wherein the quantity of dye is in the range of a single molecule to a small number of molecules.~~

~~52~~29. A laser light source that produces an amplitude modulated laser pulse train having ultrashort laser pulses.

~~53~~30. The laser light source of claim ~~52~~ 29, wherein the pulse train has a pulse duration of less than or equal to 100 picoseconds and individual pulses of varying amplitude.

~~53~~31. A method comprising:

using a laser light source to produce an amplitude modulated pulse train having a pulse width of less than or equal to 100 picoseconds and individual pulses of varying amplitude.