Mode Locked Laser Diode in a High Power Solid State Regenerative Amplifier and Mount Mechanism DIV

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A mode locked as a seed source for a solid state regenerative amplifier system is disclosed. The system includes components for forming an external cavity laser with a semiconductor amplifier, exciting and mode locking the cavity laser to emit optical pulses with a linearly time varying optical frequency, collecting and collimating the optical pulses, isolating the optical pulses and amplifying the optical pulses for a selected application. The selected applications include but are not limited to medical imaging, fuel diagnostics, ultrafast spectroscopic measurements, network synchronization, distributed optical clock network, electro-optic sampling, timing jitter reduction, a source for inducing nonlinear optical effects, and optical time domain reflectometry. A mount mechanism support for an optic system is also disclosed. The mount support includes an optic component such as a semiconductor laser diode, a semiconductor optical amplifier, and a fiber optical amplifier as well as mounts for the optic component. The mount further includes a stud for supporting the optic component, cooling and heat-sinking elements for the component, and an isolator for thermally isolating and separating the mounts from the elements. The thermal isolator includes material selected from teflon and double-panel glass. The mounts can further include a vertical mounting block with one side attached to the isolator and a second mounting block positioned perpendicular to and supporting the vertical mounting block.

5 Claims, 4 Drawing Sheets
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The invention disclosed has several key features over the prior art. The subject invention is compact, efficient, has low maintenance, electrical synchronization, low timing jitter, 110 VAC operation, provides a pre-chirped pulse, is bandgap...
This laser system has electrical synchronization capability prior VAC regenerative amplifier schemes. The invention is bandgap efficient since the laser system can be operated with excessive power requirements. The operation of FIG. 1 will now be discussed. The invention is potentially integrable. The light is appropriately polarized from the laser without the need of relying on naturally occurring lasting transitions in condensed matter.

The subject invention requires low maintenance which allows the laser system to be contained within a closed permanent structure such as computers and within satellites. This laser system has electrical synchronization capability which facilitates the operation of the laser. The invention has low timing jitter which further facilitates synchronization.

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This laser system provides a pre-chirped pulse that avoids the use of a pulse stretcher in standard chirped pulse regenerative amplifier schemes. The invention is bandgap engineerable which allows a user to generate any desirable wavelength from the laser without the need of relying on naturally occurring lasting transitions in condensed matter.

The subject invention is completely electrically pumped where an all solid state oscillator allows for mechanical robustness and enhanced reliability. The subject laser system can be integrable on chip and with optical fiber media which allows for direct fabrication with semiconductor electronics and can be manufactured in packages with sizes on the order of a computer disc.

FIG. 1 shows a mode locked diode laser in a solid state regenerative amplifier system. This design eliminates the need for an expensive $120,000 to $150,000 Argon ion pump laser and mode-locked Titanium Saphire laser oscillator. The components of the system of FIG. 1 are now defined.

Referring to FIG. 1, M1 through M7 are mirrors. Element 102 is a semiconductor multiple quantum well saturable absorber on a mirror surface structure such as a metal mirror or a dielectric mirror. 110 is an output coupler mirror that can be typically broadband and dielectric with a reflectivity of approximately between 1 and 99%. Elements 124, 126 and 132 are standard dielectric type high reflector mirrors that are used to steer the optical beam. Elements 142 and 148 are high power narrowband dielectric mirrors that help reduce amplified spontaneous emission.

Referring to FIG. 1, L1 to L4 are lenses. Elements 104, 108, 114 and 118 are focussing/collimating lenses with large numerical apertures. 106 is the SOA which is a diode such as semiconductor optical amplifier, GaAs/AlGaAs gain guide, thin active region double heterostructure, high power superluminescent laser diode. 112 refers to I which is an optical isolator that can be made from Yttrium Indium Garnet(YIG) placed within a magnetic field that can be designed to operate between 700 nanometers and 900 nanometers. 120 and 122 refer to G1 and G2 respectively which are diffractive gratings with 1800 line pairs per millimeter with a gold reflective coatings. 128 and 138 refer to PBS1 and PBS2 respectively, which are high power thin film dielectric polarizing beam splitters that can be designed to operate between 700 nm and 900 nm. Output 130 goes to any application or experiment requiring the output light pulses generated from this invention. 134 refers to FR which is a Faraday Rotator which rotates the plane of polarization depending on which direction the light is traveling. 136 is a wave plate of size $\lambda/2$ which rotates the plane of polarization of the light passing through the device. 140 refers to a pockel cell which is an electro-optic crystal that rotates the plane of polarization of light passing through the device when an electric field is applied. 144 refers to an Nd:YAG solid state laser or similar type laser which pumps or excites the solid state regenerative amplifier medium. 146 refers to the solid state regenerative amplifier gain medium such as Titanium Sapphire: Ti:Al$_2$O$_3$.

FIG. 2 shows a schematic of the mode locked semiconductor laser system of FIG. 1. Time, t is 206 fs and $P_{165}$ W, $\lambda$ is 838 nm and fs is 335 MHz. The components of FIG. 2 will now be described. 202 refers to a semiconductor multiple quantum well saturable absorber in contact with a high reflector mirror, which is similar to 112 of FIG. 1. Component 204 is a focusing/collimating lens. 206 is a beam splitter. 208 is a focusing/collimating lens. 210 is semiconductor optical amplifier(SOA) or a travelling wave amplifier. 212 and 214 comprise a bias tee. 216 is a focusing/collimating lens. 218 is an adjustable slit. 220 is a four prism sequence. 222 is a collimating/focusing lens. 224 is an output coupler. 226 is a collimating/focusing lens. 228 is a turning mirror. 230 is an isolator. 240 refers to a semiconductor optical amplifier. 242 is an optional stretched/compressed amplified optical pulses which goes to diagnostics as an autocorrelator, photodetector, spectrometer, experiment, application, and the like. 244 are the stretched...
amplified output optical pulses which goes to diagnostics as an autocorrelator, photodetector, spectrometer, experiment, application, and the like. 250 and 260 are diffraction gratings. 252 is a reflecting mirror. 254 and 258 are lenses in a telescope configuration. 256 is an adjustable slit similar to component 218.

A description of the operation of the components of FIG. 2 will now be described. The SOA 210, is placed in an external optical cavity formed by output coupler 224 and the MQW saturable mirror 202. Both direct current DC and radio frequency RF current is supplied through the bias tee 212, 214. The light emission from SOA 210 is collected and collimated by lenses 208 and 216. Light is focussed on MQW absorber/mirror 202 by lens 204. Light is then directed through slit 218, to control the transverse mode profile. Light is directed through prism sequence P 220 and focussed onto the output coupler 224 by lens 222. When appropriately biased with electric current and optically aligned, the laser becomes mode locked, emitting optical pulses with a linearly time varying frequency (chirped pulses). The optical pulses are collected and collimated by lens 226 and directed to an optical isolator 230 by a turning mirror 228. The optical pulses are amplified in SOA 240 and can either be utilized directly at output 244, or directed to an optical dispersion element/compensator 250-260. The output from the dispersion apparatus 242 are high power optical pulses which can be diagnosed, utilized in measurements, experiments, and the like.

FIG. 3 is a plot illustrating the performance of the laser system of FIG. 1. In FIG. 3, a generated ultrafast optical pulse is shown compared to the second harmonic intensity autocorrelation function plotted versus the time delay. This plot shows an optical pulse of 207 femtoseconds in duration.

FIG. 4 shows a schematic diagram of what the optical pulse looks like at several points in the laser system of FIG. 2. In reference to FIG. 4, 402 refers to a compact, efficient mode locked laser such as a mode locked semiconductor laser. 404 refers to a compact, efficient optical amplifier such as the SOA. Components 406 and 408 refer to mirrors such as to direct light into an optical temporal dispersion system. 410 is an optical dispersion system which can temporally expand or compress optical pulses. And 412 is the resultant high power ultrafast optical pulses which can be used for measurements, experiments, and the like. The operation of FIG. 4 corresponds to the operation of components 220 to 260 of FIG. 2.

The laser system described in FIGS. 1 through 4 has application in wide areas such as but not limited to medical imaging, fuel diagnostics, ultrafast spectroscopic measurements, network synchronization, distributed optical clock networks, electro-optic sampling, timing jitter reduction, a source for inducing nonlinear optical effects, and optical time domain reflectometry.

In medical imaging applications, ultrashort optical pulses can be used to image structure in optically dense/diffuse media by relying on optical time of flight techniques. In fuel diagnostic applications, ultrashort high power optical pulses can be used as a tool to measure the dynamics of electrons, atoms, molecules and other condensed matter particles on an ultrafast time scale. In network synchronization applications, a single RF oscillator can be used to drive several mode locked lasers with identical optical cavity lengths. The resultant is several independent, high synchronized optical pulse trains which can be used as master timing devices in computers, and local area networks and the like.

In optical clock distribution applications, the precise timing of the generated optical pulse train can be used as analogous ticks of a clock in any system/network/instrument/application which requires a master timing signal. The high output power from the laser allows the optical clocking signal to be split many times thus providing an identical timing signal to many independent locations.

In electro-optic sampling applications, the mode locked diode laser is driven by an RF oscillator. This RF oscillator can also be used to trigger ultrafast electrical signals. Since both the laser and high speed electrical signals are driven by the same RF oscillator, minimal timing uncertainties exist between the ultrafast optical and electronic signals.

In timing jitter reduction, this is a random fluctuation between the time of arrival of two successive optical pulses in the generated optical pulse train. This small timing jitter is the key ingredient which allows one to use the laser in clock distribution, network synchronization and electro-optic sampling.

As a source for inducing nonlinear optical effects, the peak powers achieved by this laser system are sufficient to induce many nonlinear optical effects. Such effects include but are not limited to SHG (second harmonic generation), SPM (self-phase modulation), 4 WM (four wave mixing), and TPA (two photon absorption).

In optical time domain reflectometry, this technique is basically an optical radar technique. Here, a short optical pulse is emitted and directed towards an object. The reflected light from the object is collected and the amount of time elapsed between the emitted and reflected optical pulse is measured giving information about the position and location of the object and target.

MOUNT MECHANISM

FIG. 5 shows a side view of the laser mount 500. FIG. 6 shows a view of the laser mount 500 of FIG. 5 along arrow A. The components of FIGS. 5 and 6 will now be defined. 502 refers to a thermoelectric cooler such as a Melcor thermoelectric cooler, or other Peltier cooling element. 504 is a heat sink for removing heat. 506 is a stud or any other mounting block for a semiconductor optical laser or amplifier. 508 refers to a semiconductor laser diode, semiconductor optical amplifier, fiber optical amplifier, or any other device which requires operating at a temperature different from the environment and cannot experience any movement while being cooled by the Peltier cooling element. 509 are electrical contacts. 510 is a thermal isolation such as any material or device which does not conduct heat such as but not limited to teflon and double panel glass. 512 and 514 respectively refer to mounting blocks such as any material capable of providing sufficient strength and rigidity to support the laser diode, stud, thermoelectric cooler and heat sink such as copper.

Referring to FIGS. 5 and 6, the operation of mounting mechanism 500 will now be discussed. Mounting structure 500 separates mounting blocks 512 and 514 from cooling elements 502 and from heat-sinking elements 504 using thermal isolation means 510. This separation thus avoids small movements caused by the thermoelectric cooler 502 when in operation. Mounting block 514 supports the entire mounting structure. Mounting block 512 supports the laser/stud 506, 508, 509, and is thermally isolated from these components by thermal isolator 510. With this arrangement there is no heat transfer to the mounting structure as laser/stud 506, 508, 509, gets heated by current injection through electrical contact 509. Cooling element 502 provides a
A rigid base mount attached to the first side surface of the submount for rigidly supporting the submount; cooling and heat-sinking means for cooling the optic component, the cooling and heat-sinking means attached to and cantilevered from the second side surface of the submount; and a thermo-isolator means attached between the submount and the vertical mount for eliminating heat transfer between the optic component and the vertical mount, wherein expansion and contraction movements caused by the cooling and heat-sinking means which would be transferred and passed to the optic component are eliminated.

2. The cantilever mount support for the optic system of claim 1, wherein the submount further includes: a stud for supporting the optic component.

3. The cantilever mount support for the optic system of claim 1, wherein the thermal isolator includes material selected from at least one of: Teflon and double-panel glass.

4. The cantilever mount support for the optic system of claim 1, wherein the rigid base mount further includes: a vertical mounting block with an upper side attached to the first side surface of the submount; and a second mounting block positioned perpendicular to and supporting the vertical mounting block.

5. The cantilever mount support for the optic system of claim 1, wherein the cooling and heat-sinking means further include: a thermoelectric cooler attached to the second surface of the submount for cooling the optic component; and a heat sink element attached to an opposite side of the thermoelectric cooler.