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Raman fibre pulsed laser

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***Abstract**: Raman fibre pulsed laser comprises optically coupled pumping radiation source, which supports polarisation of the radiation of a fibre ring resonator, comprising a Raman amplification fibre which converts pumping radiation into radiation of a first or higher Stokes component of Raman scattering. The laser also includes a fibre spectral information module for inputting pumping radiation into the ring resonator, which enables to input pumping radiation into the ring resonator and transmits amplified radiation of the Raman pulsed laser, a polarisation-dependent splitter for outputting radiation from the resonator and at least one isolator which provides unidirectional generation of radiation. The laser resonator includes an active radiation mode locking element based on an amplitude or phase modulator. EFFECT: enabling generation of stable coherent pulses with repetition frequency higher than 1 MHz in a wide spectral range using pumping radiation with different wavelengths.*
5 cl, 3 dwg

Description

The present invention relates to lasers - gears for generation of coherent of electromagnetic waves and is industrially applicable in devices and systems using laser radiation.

From the prior art known fiber ring Erbium laser mode-locked radiation implemented using intracavity amplitude modulation of radiation at a frequency equal to the intermode interval of the laser resonator (JD Kafka et al. Mode-locked erbium-doped fiber laser with soliton pulse shaping. Opt. Lett., 14 (22), pp. 1269-1271 (1989)). The disadvantage of this technical solution is that the spectral range of the radiation pulses is limited by the working spectral range of erbium laser, the width of the spectral range is at best a few tens of nanometers near the wavelength of 1550 nm, this relatively narrow operating spectral range given the characteristics of the active medium - fiber, doped with erbium ions. Also used in the laser resonator fiber without the support of the polarization of the radiation does not suppress the effect of the nonlinear evolution of the polarization of radiation (VJ Matsas et al. Self-starting passively mode-locked fibre ring soliton laser exploiting nonlinear polarisation rotation. Electron. Lett. 28, 1391 (1992)), which initiates passive mode locking of radiation and is shown simultaneously with the active mode-locked radiation. Uncontrolled parasitic passive mode locking of radiation brings instability in the generation of laser active mode locking of the radiation, which is manifested in a much larger time "jitter" pulse and a much increased amplitude instability pulses, which can even lead to lacks of individual pulses of their sequence .

The closest to the claimed technical solution is a fiber laser with active mode locking of radiation using a dynamically tunable optical filter and the feedback element for auto speed adjustment spectral bandwidth of the optical filter (EP 2264841 A2, publ. 22.12.2010, Bulletin 2010/51) . Synchronization modes of radiation in this laser is carried out by sweeping the laser line with a frequency that depends on the round-trip time of the laser resonator. This decision provides (as an option) to use in the laser cavity supporting the polarization of the radiation elements and the element defining the polarization of radiation - polarization-dependent coupler and Raman gain medium. The disadvantage of this solution is the need of using a relatively long laser cavity to reduce the frequency sweep so with what may be reconstructed spectral-selective tunable filter (not more than 1 MHz: CM Eigenwillig et al. Picosecond pulses from wavelength-swept continuous-wave Fourier domain mode-locked lasers. Nature Communications, 4, article number: 1848 (2013)). This limits the pulse repetition frequency of the laser the magnitude of 1 MHz.

The task to be solved by the claimed invention is to provide a compact Raman fiber pulsed laser with a repetition rate of coherent pulses of greater than 1 MHz, while significantly improving some of the key

parameters of the radiation: at least a few times reduction of the time "jitter" pulse and at least a few times The decrease in amplitude pulses of instability. High pulse repetition rate (> 1 MHz) allows for a fundamentally different mechanism of interaction of radiation with matter - ablation of the interaction of radiation with a solid surface and photomodification material in contact with the bulk transparent medium. Furthermore, as the Raman medium in the gain medium produces the same parameters of the radiation in the broad spectral range by the use of pump radiation having different wavelengths, as well as through the use of various radiation stimulated Raman Stokes components (Raman) scattering.

This problem is solved by the fact that in a Raman fiber pulsed laser comprising optically coupled pumping radiation source that supports the polarization of the light fiber ring resonator containing a Raman amplifying fiber that converts the pump radiation to the radiation of the first or higher Stokes components of stimulated Raman (Raman) scattering, at least one fiber module of spectral information for introducing the pump radiation into the ring resonator, allowing you to enter the pump radiation into the ring resonator and transmits the radiation being amplified Raman pulsed laser, at least one polarization-dependent coupler to the emission output from the resonator, at least one insulator, providing unidirectional generation radiation according to the invention introduced into the laser resonator element active modelocking radiation based on the amplitude or phase modulator.

In particular, as the Raman amplifying fiber can be used as a glass optical fiber and glass optical fiber doped with oxides of germanium, phosphorous, and combinations thereof, wherein in the oxide matrix may include a compound of the chemical elements Si, N, Ga, Al , Fe, F, Ti, In, Sn, Ba, Ta, Zr, Bi.

In particular, the source of pump radiation Raman pulsed laser can serve as a Raman laser using as reinforcing fibers glass fibers doped with oxides of germanium, phosphorous, and combinations thereof, wherein in the oxide matrix may include a compound of the chemical elements Si, N, Ga, Al, Fe, F, Ti, B, Sn, Ba, Ta, Zr, Bi, while the Raman laser resonator formed by two fiber Bragg grating having perpendicular or inclined strokes beam and reflecting radiation of the first Stokes component of the stimulated Raman (Raman) scattering.

In particular, the source of pump radiation Raman pulsed laser can serve two Raman laser using as reinforcing fibers glass fibers doped with oxides of germanium, phosphorous, and combinations thereof, wherein in the oxide matrix may include a compound of the chemical elements Si, N, Ga, Al , Fe, F, Ti, B, Sn, Ba, Ta, Zr, Bi, wherein the resonators two Raman lasers form four fiber Bragg gratings having perpendicular beam or slanted strokes and reflect radiation of the first and second Stokes components of stimulated Raman (Raman) scattering.

In particular, to reduce the duration of the laser pulses generated may be used by the electrical impulses that control the elements of the active mode locking, the duration of which does not exceed the duration of the generated pulses.

The prior art has not disclosed a device having the claimed set of attributes, i.e. It has novelty.

The features defined in the description and claims, the prototype can not provide the claimed technical result. Laser mode-locked radiation on the basis of spectral lines sweep generation (Fourier domain mode-locked laser, FDML) are not capable of generating svipirovat line over a wide range (5-10 nm and more) with a frequency of greater than 1 MHz, so the pulse repetition frequency of the laser is limited the value of 1 MHz. To reduce the frequency sweep generation line in FDML-laser uses the resonator length (longer than 1 km) with a mode frequency less than 1 MHz. A significant increase in the length of the resonator fiber laser mode-locked radiation leads to the fact that in such a resonator is realized mainly lasing pulse trains (picosecond or nanosecond) filled with a stochastic sequence of shorter pulses (S. Smirnov et al. Three key regimes of single pulse generation per round trip of all-normal-dispersion fiber lasers mode-locked with nonlinear polarization rotation. Optics Express, Vol.20, Issue 24, pp.

27447-27453 (2012)). These incoherent pulses, often called in the literature "noise-like" ("noise-like"), have a very limited application due to their specific structure, as well as due to instability of the parameters of pulses caused by stochastic filling trains - increasing the time "jitter" pulses, reaching a few percent of the interpulse time interval and increased instability amplitude pulses, reaching several tens of percent.

Active mode locking radiation allows for generation mode of coherent pulses MHz and a repetition frequency having a substantially broader field of application and have a much more stable radiation parameters - time "shaking" pulses does not exceed one percent of the interpulse time interval, amplitude instability pulses not more than several percent.

The technical result provided by the above combination of features, is to achieve a compact Raman fiber pulsed laser repetition frequency of coherent pulses of greater than 1 MHz, while significantly improving some of the key parameters of the radiation: at least a few times reduction of the time "jitter" of pulses and at least several times a decrease amplitude pulses of instability. In addition, the use of Raman gain medium allows you to convert the radiation spectrum - to shift it to longer wavelengths corresponding to the emission of the first or higher Stokes components of stimulated Raman (Raman) scattering.

Should be noted that audio one separately details commitment made device does not gives such effect what gives totality stated features. Before filing this application was not obvious that the combination of the claimed signs would solve the problem of creating a compact Raman fiber pulsed laser with a repetition rate of coherent pulses of greater than 1 MHz, while significantly improving some of the key parameters of the radiation: at least a few times reduction of the time "jitter" of pulses and how at least several times reduce instability amplitude pulses.

Essence invention is explained following schemes.

FIG. 1 shows the Raman fiber pulsed laser: 1 - pumping radiation source, 2 - fiber module spectral information 3 - Raman amplifying fiber, 4 - element active mode locking, 5 - insulator 6 - polarization-dependent coupler 7 - output study of laser .

FIG. 2 is a diagram of a Raman fiber laser pulse, wherein the source of pump radiation of the Raman fiber laser is a pulsed laser Raman resonator formed by two fiber Bragg grating 8 reflecting radiation of the first Stokes component of the stimulated Raman (Raman) scattering.

FIG. 3 is a diagram of a Raman fiber pulsed laser in which the radiation source pumping Raman fiber pulsed laser are two Raman laser resonators which form a four fiber Bragg gratings which reflect light of the first (lattice 8) and second (plate 9) Stokes components of stimulated Raman (Raman) scattering.

The device operates as follows:

pump radiation generated by the source 1, the optical pumping radiation, through the fiber module spectral information 2 enters the Raman amplifying fiber 3; generation of laser is carried out in a ring resonator, a unidirectional lasing provided an insulator 5 for the emission output from the resonator is a polarization-dependent coupler 6, which also performs the function of the polarizer radiation. Mode locking laser element is made active mode locking of radiation 4 on the basis of the amplitude or phase modulator. To eliminate the influence of the parasitic effect of nonlinear polarization evolution of all elements of the resonator made of fiber supports the polarization of radiation. The laser generates pulses of radiation in the spectral region corresponding to the emission spectrum of the first Stokes component of stimulated Raman (Raman) scattering relative to the spectrum of the pump light.

When using the circuit Raman fiber pulsed laser in which the radiation source pumping Raman fiber pulsed laser is a Raman laser resonator is formed by two fiber Bragg gratings 8, reflecting the radiation of the first Stokes component of stimulated Raman (Raman) scattering laser generates pulses of radiation in the spectral range, corresponding to the emission spectrum of the second Stokes component of stimulated Raman (Raman) scattering relative to the spectrum of the pump light.

When using the circuit Raman fiber pulsed laser in which the radiation source pumping Raman fiber pulsed laser are two Raman laser resonators which form a four fiber Bragg gratings which reflect light of the first (lattice 8) and second (plate 9) Stokes components of stimulated Raman (Raman) scattering laser generates pulses of radiation in the spectral region corresponding to the emission spectrum of the third Stokes component of stimulated Raman (Raman) scattering relative to the spectrum of the pump light.

When the scheme of the Raman fiber laser pulse, wherein the source of pump light of a Raman fiber laser pulse are one or two Raman laser of resonators can be formed reflecting fiber Bragg gratings having a beam perpendicular or oblique strokes.

To reduce the duration of the pulses generated by the need to use electrical impulses, controls the active mode locking, the duration of which does not exceed the duration of the generated pulses.

Claims (5)

1: Raman fiber laser pulse containing optically coupled pumping radiation source that supports the polarization of light fiber ring resonator containing a Raman amplifying fiber that converts the pump radiation to the radiation of the first or higher Stokes components of stimulated Raman (Raman) scattering at least one fiber module spectral information for introducing the pump radiation into the ring resonator, which allows to enter the pump radiation into the ring resonator and transmits the amplified radiation Raman pulse laser, at least one polarization-dependent coupler for outputting the radiation from the resonator, at least one insulator, providing unidirectional lasing, characterized in that the resonator Laser introduced an element of active mode locking of the radiation on the basis of the amplitude or phase modulator.

2: Laser according to Claim. 1, characterized in that as the Raman amplifying fiber can be used as a glass optical fiber and glass optical fiber doped with oxides of germanium, phosphorous, and combinations thereof, wherein in the oxide matrix may include a compound chemical elements Si, N, Ga, Al, Fe, F, Ti, B, Sn, Ba, Ta, Zr, Bi.

3: Laser according to Claim. 1, characterized in that the Raman pump light source laser pulse can serve Raman laser using as reinforcing fibers glass fibers doped with oxides of germanium, phosphorous, and combinations thereof, wherein in the oxide matrix may include chemical compound element Si, N, Ga, Al, Fe, F, Ti, B, Sn, Ba, Ta, Zr, Bi, wherein the cavity of the Raman laser formed by two fiber Bragg grating having perpendicular beam or slanted strokes and reflect radiation of the first Stokes component Stimulated Raman (Raman) scattering.

4: Laser according to Claim. 1, characterized in that the Raman pump light source laser pulse can serve two Raman laser using as reinforcing fibers glass fibers doped with oxides of germanium, phosphorous, and combinations thereof, wherein in the oxide matrix may include a compound chemical elements Si, N, Ga, Al, Fe, F, Ti, B, Sn, Ba, Ta, Zr, Bi, wherein the resonators two Raman lasers form four fiber Bragg gratings having perpendicular beam or slanted strokes and reflect radiation of the first and second Stokes components of stimulated Raman (Raman) scattering.

5: Laser according to Claim. 1, characterized in that the duration of the electrical pulse control element active modelocking radiation less than the duration of the generated pulses.