

The present invention relates to power laser generators in which it is possible to control the angular direction of the output beams.

5 In numerous fields, for example telemetry and the guiding of missiles, a laser beam is most often used as a reference element, the coherence, both temporal and spatial, of this laser beam enabling a "narrow and imaginary line" to be defined over a relatively long trajectory.

10 For example, for guiding terrestrial missiles over short distances, a laser generator of the "helium-neon" type having a few milliwatts of power is used. The beam defined by this type of generator is sufficiently narrow in order to be used as a reference for guiding or
15 for telemetry. In addition, the laser generator is sufficiently small and compact easily to allow its output beam to be oriented in a given direction. In order to do this, it suffices to mount the laser generator on a mounting plate and to move this mounting plate along two
20 or three axes by means of motors. However, this operation gives the desired result only if the necessary speed of angular movement is not very great.

In order to guide missiles, especially terrestrial missiles, which have to move relatively rapidly,
25 deflection cells have been produced which are arranged on the laser beam itself, in the output of the laser generator, and which are controlled electrically in the manner of, for example, the acoustooptic static deflectors well known by those skilled in the art. The advantage of these
30 deflectors is that they respond very rapidly to the deflection commands which are given them. On the other hand, they have a major drawback, that of being able to deflect only low-power beams. Indeed, in the case of the deflection of power laser beams, deflectors are very
35 rapidly deteriorated by these beams themselves and their effectiveness decreases significantly when the imposed angle of deviation increases, that is to say the power of the deflected beam decreases as a function of the increase in the angle of deviation. EP-A-0,292,353

describes a device for angularly controlling a laser beam, comprising, in succession, a controllable deflection device, a holographic multiplexer and a system of shutters.

5 The object of the present invention is to produce a power laser generator which can emit a laser beam, the angular output direction of which, in relation to the generator itself, can vary over a wide angular field, whilst keeping the qualities, especially the spatial and
10 temporal qualities, of the laser beams emitted by generators known in the prior art.

 More precisely, the subject of the present invention is a power laser generator with control of the emission direction of the output beam, including, in
15 succession, on a same optical propagation axis of the beam:

 means for emitting a pilot laser beam of a given wavelength,

 a controllable deflector,
20 a beam splitter,
 an amplifier medium amplifying at the wavelength of the pilot beam, and

 a non-linear phase-conjugation mirror, the said beam splitter separating the pilot laser beam from the
25 amplified beam.

 Other characteristics and advantages of the present invention will appear during the following description which is given, with respect to the attached drawings, by way of illustration, but which is in no way
30 limiting, in which drawings Figures 1 to 3 represent very schematically various embodiments of a laser generator according to the invention.

 Figure 1 shows a first embodiment of a power laser generator, the emission direction 1 of the output
35 beam 2 of which is controlled as a function of a control command applied to a control input 3.

 This generator includes means 4 for emitting a pilot laser beam 5 of low power but of high quality, especially aiming, oscillation-mode and stability

quality. These means 4, for example, are constituted by an oscillator laser generator having a resonant cavity of the Fabry-Pérot type.

5 This pilot laser beam 5 emitted by the generator 4 falls on the entrance window 6 of a deflector 7, for example of the acoustooptic type, such as a TeO_2 or LiNbO_3 Bragg cell. Such elements are known per se and will not be described in more detail here. After having passed through the deflector 7 and having
10 emerged via its exit window 8, the pilot laser beam 5 passes through a splitter 9, for example of the polarisation type. In this case, a polariser 11, for example a quarter-wave plate 12, is placed in the optical path of the pilot laser beam at the output 10 of the
15 splitter 9.

The laser beam 13 obtained as output from this polariser 11 is next sent into a laser amplifier medium 14 matched to its wavelength. The output 15 of this amplifier medium is coupled to a mirror 16 constituted, according to one characteristic of the invention,
20 by a non-linear medium whose function is to phase conjugate the incident wave 17 coming from the laser amplifier medium 14 with the reflected wave 18 so that, if the incident wave includes phase distortions, this so-called
25 "conjugate" mirror sends back a reflected wave which includes phase distortions identical to those of the incident wave, contrary to "conventional" mirrors which send back a reflected wave which includes opposite distortions.

30 Now, during the passage in the amplifier medium 14, the wave undergoes phase distortions due, for example, to the well-known thermal lens effect connected with the pumping 20 produced in this amplifier medium. Thus, in general, the rays of the beam which are located
35 at the centre are "retarded" in relation to those at the periphery and in relation to the direction of movement of the wave.

With the conjugate mirror 16 sending back the beam with the characteristic such as defined hereinabove,

the rays which were "retarded" are, before undertaking the second passage in the amplifier medium 14, "advanced" with the same amplitude in relation to the direction of movement of this reflected wave. The second passage then

5 makes it possible to compensate for the distortion due to the first passage and to restore the phase quality of the initial wave, whilst amplifying the power of the beam.

In the example illustrated, the means 19 for coupling the exit face 15 of the amplifier medium 14 to

10 the conjugate mirror 16 are constituted by a focusing lens.

The conjugate mirror 16 is itself constituted by a non-linear medium perfectly suited to create a conjugate wave capable of compensating for, especially, the

15 phase distortions of the incident wave. These media are, for example, a gas such as methane (CH_4), sulphur hexafluoride (SF_6), etc., in which the stimulated Brillouin effect develops, or electrooptic crystals, such as gallium arsenide (GaAs) etc., in which crystals the

20 photorefractive effect develops.

However, it should be noted that among the materials for non-linear media, those producing a stimulated Brillouin effect are advantageously suitable for compensating for the phase distortions of the amplified

25 laser beams which operate in pulse mode with high peak powers, for example from 200 to 500 mJ for 10 ns pulses.

The laser generator whose structure has just been described with respect to Figure 1 operates in the following manner:

30 The pilot laser generator 4 delivers a laser beam 5 of low power and of high quality. This pilot laser beam 5 is deflected, as a function of the control signal applied to the input 3 of the deflector 7, in the desired angular direction. This deflection is performed according

35 to a principle known per se and is controlled by controlling the frequency of the microwave signal applied especially to the crystal which constitutes the essential element of the deflector 7.

The beam thus deflected passes freely through the

splitter 9 which behaves, for the wave of this incident beam, practically as a parallel-faced plate transmitting virtually the entire beam. Then, it passes a first time through the quarter-wave plate 12. Next, it is amplified by a first passage in the amplifier medium 14 and by a second one in the opposite direction, after reflection at the conjugate mirror 16 which enables, as explained hereinabove, the distortions due to the amplification to be corrected.

Next, the laser beam passes a second time through the quarter-wave plate 12 before penetrating the splitter 9 once again. Since the beam passes through the quarter-wave plate twice during the first passage, it is polarised circularly and then, during the second passage, linearly at ninety degrees to the incident wave. The splitter 9, especially by discrimination of the polarisation, can thus completely deflect towards the output of the generator a power laser beam 2, preventing it from falling on the controllable deflector 7, this preventing it from being damaged or from deteriorating.

The angular deviation imposed by the deflector 7 on the low-power incident beam 5 and existing at the input of the amplifier medium 14 is the same again at the output of the splitter 9, this situation being demonstrated very easily with the aid of the geometrical construction of the propagation of the beams in the various media.

Figure 2 shows a second embodiment of a laser generator according to the invention, which, in its principle, is identical to that of Figure 1, but in which the laser amplifier medium 30 is of the "slab" type ensuring, after a plurality of reflections 31 of the beam 32, very good homogeneity of the gain in the amplification of the beam.

This type of generator is particularly suited for solid-state laser amplifier media, for example neodymium or YAG (Yttrium-Aluminium Garnet) type bars or plates, these configurations, in particular, being compatible with a multi-passage of an incident wave of a wavelength

in the vicinity of 1.06 micrometre [sic].

With a laser generator such as illustrated in Figure 2, the Applicant has produced a prototype in which the pilot laser 33 is a pumped diode laser having an energy of 2 mJ for 10 ns pulse durations with a repetition rate equal to about ten Hertz.

The acoustooptic deflector 34 is a TeO_2 or LiNbO_3 Bragg cell which possesses a resolution of 10^3 points, with an angular deflection of $\pm 30^\circ$ for a laser beam 35 diameter of the order of 1 mm, or of $\pm 3^\circ$ for a beam diameter of the order of 10 mm, the efficiency of the deflection easily exceeding 50 %.

The amplifier medium 30 is a Nd-YAG optically pumped by a flashlamp or by an array of semiconductor lasers, the gain in the established prototype being at 20 db and enabling, after two passages of the laser beam, an output energy equal to 200 mJ to be obtained.

As regards the conjugate mirror 36, this is constituted by a self-pumped CH_4 Brillouin cell under reflection conditions optimized at a wavelength equal to 1.06 micrometre [sic], the CH_4 gas therein being at a pressure of 100 bar and the reflectivity coefficient then being greater than 80 %.

Figure 3 shows a third embodiment of a laser generator according to the invention, identical in its basic principle to the two embodiments described herein-above, but in which the laser amplifier medium 40 is constituted by a second part 42 of a "laser plate", the first part 41 of which constitutes the pilot laser generator itself, for example a Nd-YAG. In that case, the laser plate has a relatively large cross-section and the amplification is obtained by a multi-passage, in the second part 42, of the beam deflected by the deflector 47, this multi-passage being produced by multiple reflections at mirrors 43, or total-reflection prisms, external to the laser plate.

In the embodiment illustrated, the second part 42 of the laser plate 40 is passed through six times by the deflected part 45 of the pilot laser beam. One of the

advantages of this configuration is that it makes it possible to obtain, with a relatively short laser plate, a very long laser amplifier medium, for example having a triple length for the embodiment illustrated in Figure 3.

5 These three structures for a laser generator according to the invention make it possible to obtain self-correction of the phase distortions induced in any high-gain amplifier medium, especially by the thermal lens effect. The conjugate wave is generated strictly in
10 the same direction as the incident wave, even for an angular deflection equal to $\pm 30^\circ$. The angular deflection of the low-energy pilot beam is transferred to the power beam and the deflected amplified wave has the same spatial qualities as the incident pilot wave.

15 Of course, the configurations described are compatible with any other means for angularly deflecting the incident beam, for example an optomechanical and/or electrooptic device. Likewise, a two-dimensional deflection of the beam is obtained by inserting an X-Y deflection device, for example two crossed acoustooptic cells,
20 into the cavity.



Patent Claims

1. Laser power generator with control of the emission direction (1) of the output beam (2), including, in succession, on the same optical propagation axis of the beam:
- 5 means (4) for emitting a pilot laser beam (5) of a given wavelength,
- a controllable deflector (7),
- a beam splitter (9),
- 10 a laser amplifier medium (14), amplifying at the wavelength of the pilot beam, and
- a non-linear phase-conjugation mirror (16), the said beam splitter separating the pilot laser beam from the amplified beam.
- 15 2. Laser generator according to Claim 1, characterised in that the means (4) for emitting a pilot laser beam (5) of a given wavelength comprise a pilot laser generator delivering a low-power beam having good aiming, oscillation-mode and stability quality.
- 20 3. Laser generator according to either Claims 1 or 2, characterised in that the said controllable deflector (7) is constituted by an acoustooptic-type deflector.
4. Generator according to Claim 3, characterised in that the said acoustooptic deflector is a Bragg cell,
- 25 especially a TeO_2 or LiNbO_3 Bragg cell.
5. Generator according to one of the preceding claims, characterised in that the said beam splitter (9) is constituted by a polarisation splitter and a polariser (11) such as a quarter-wave plate (12).
- 30 6. Generator according to one of the preceding claims, characterised in that the said non-linear phase-conjugation mirror (16) is constituted by a non-linear medium.
7. Generator according to Claim 6, characterised in that the said non-linear medium is constituted by at least one of the following elements: a gas such as methane (CH_4) or sulphur hexafluoride (SF_6), in which gases the stimulated Brillouin effect develops, and electrooptic crystals, such as gallium arsenide (GaAs),
- 35



in which crystals the photorefractive effect develops.

8. Generator according to one of the preceding claims, characterised in that the said laser amplifier medium (14) is of the "slab" type (30).

- 5 9. Generator according to one of Claims 1 to 7, characterised in that the said laser amplifier medium (40) is constituted by a second part (42) of a "laser plate", the first part (41) of which constitutes the pilot laser generator, the said laser plate having a
- 10 relatively large cross-section and the amplification being obtained by a multi-passage of the beam deflected in the second part (42), the multi-passage of the beam being produced by multiple reflections on mirrors (43), or total-reflection prisms, external to the laser plate.
- 15 10. Laser generator according to one of Claims 1 to 9, characterised in that it comprises means (19) for coupling the exit face (15) of the amplifier medium (14) to the non-linear phase-conjugation mirror (16), these said means being constituted by a focusing lens.