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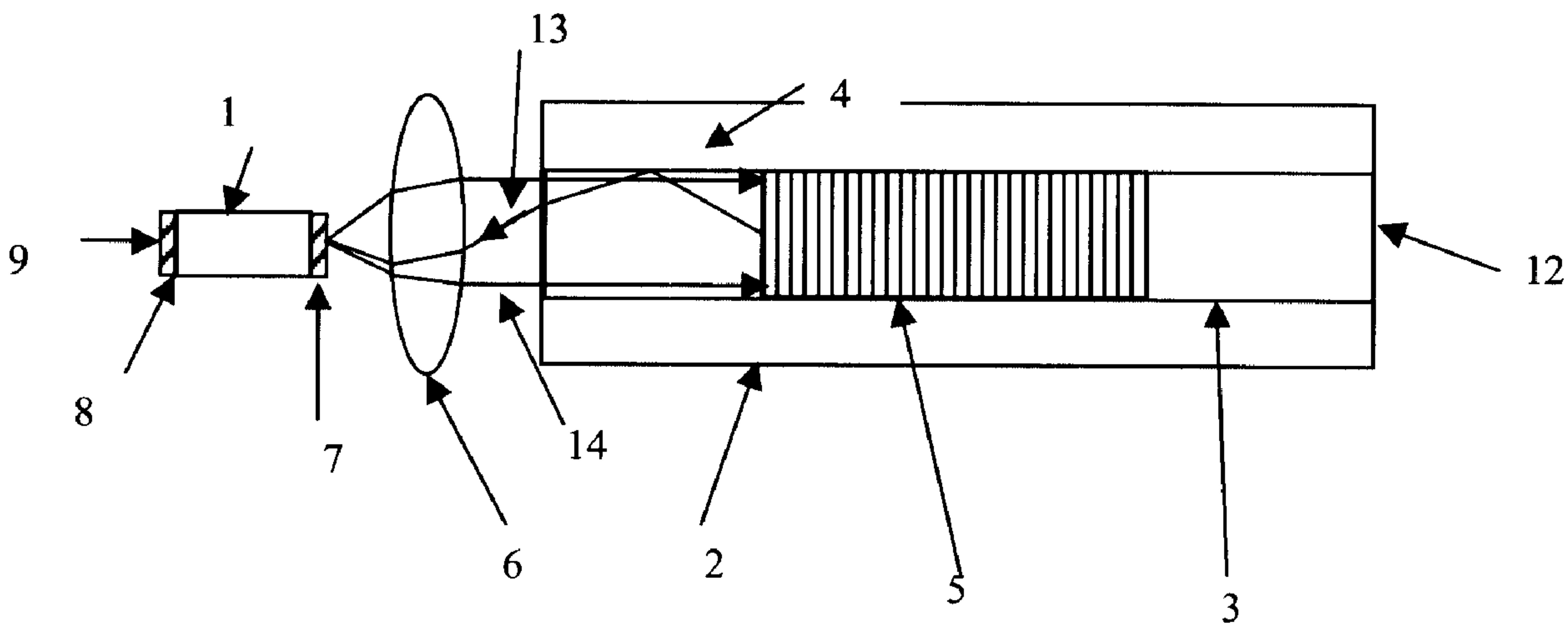

(57) Abrégé/Abstract:
This invention relates to an external cavity laser made with a semiconductor light emitting source coupled to a grating in a multimode fibre. Applications include enhanced stability for high output-power operation for pumping high-power fibre lasers and amplifiers.

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June 15, 2002

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ABSTRACT

This invention relates to an external cavity laser made with a semiconductor light emitting source coupled to a grating in a multimode fibre. Applications include enhanced stability for high output-power operation for pumping high-power fibre lasers and amplifiers.

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DISCLOSURE

BACKGROUND TO THE INVENTION

Traditionally, high-power operation of semiconductor lasers has been achieved by the use of the Master Oscillator and Power Amplifier (MOPA) configuration. In this scheme, a high-quality low power laser is coupled to a power amplifier to increase the laser power. MOPA lasers are normally fabricated in single piece of semiconductor material in which the waveguide oscillator section is immediately followed by a tapered amplifier section which allows the mode volume to increase, thus making it easier to couple to single mode fibre. However, for many applications it is necessary to extract high power from a single chip of semiconductor which is multi-mode and to couple it to a multimode fibre laser or fibre amplifier. A simple optical pumping configuration in which a multi-mode laser source (transverse and longitudinal modes) is directly coupled to the cladding of a fibre laser or amplifier, which has a single-mode core doped with one or more rare-earth elements, such as erbium and/or ytterbium, have been demonstrated. Here, the principle of operation of the laser depends on the absorption of the pump radiation from the many modes in the cladding modes as the modes traverse the core over long lengths, typically several centimeters to meters. Unfortunately, the absorption spectrum of the rare-earth ions can be narrow, peaking over only a few nanometers, requiring the pump lasers to match the wavelength of the absorption spectrum. Since the wavelength of the pump laser is temperature sensitive, the gain in the fibre amplifier or laser can vary considerably in time as the ambient temperature varies, unless the laser temperature is stabilized by cooling.

Recently, a scheme has been proposed to stabilize the wavelength of a laser by the using a nominally tilted fibre Bragg grating written into the core of a single-mode fibre and coupling the light from the semiconductor gain chip to it, forming a ring laser (Canadian Patent Application filed June 3, 2002, "Ring Laser", Inventor - Raman Kashyap, Applicant - PhotoNova Inc.). This scheme allows high-power operation of the laser while providing additional temperature stability. The method of operation is based on the coupling of many modes in the cladding to the core mode in counter propagating directions to form a ring configuration.

In the invention described here, we propose an alternative scheme using a multimode optical fibre.

DETAILED DESCRIPTION

The embodiment of the invention discussed here is illustrated schematically in Fig. 1. Referring to Fig. 1, light from the front facet of a semiconductor gain chip (1), which may or may not be coated with an anti-reflection dielectric film (7), is coupled to a multimode fibre (e.g. Corning multimode graded index fibre, or multimode step-index fibre) (2), typically via a lens (6). The rear facet (8) of the light emitting chip can be coated with a high reflection dielectric coating (9). Typical dimensions of the fibre are a core (3) diameter of 50 microns with a cladding (4) diameter of 125 microns, although these dimensions may be varied to suit the application. The core generally contains germania which has a higher refractive index than the silica cladding, forming a multimode waveguide. Germania renders the core photosensitive and a Bragg grating (5) can be written using standard methods as described by Raman Kashyap in *Fibre Bragg Gratings*, Academic Press 1999, Chapter 3. This Bragg grating (5) reflects all modes at different wavelengths propagating in the core which satisfy the phase-matching condition. The reflection coefficient for each mode depends on the type of the mode and the transverse distribution of the refractive index variation of the grating. As a result, a bunch of wavelengths in a distribution of modes are reflected by the grating. Typical ray paths from and to the light emitting source are respectively shown in Fig 1 as 13 and 14. With a tilt in the planes of the grating 10 as shown schematically in Fig. 2, the distribution of the reflection coefficient of the various modes can be altered significantly.

More particularly, the large core radius of the fibre allows coupling to a few modes; additionally a narrower bandwidth of coupling at an one wavelength is achieved, as has been described by Raman Kashyap in *Fibre Bragg Gratings*, Academic Press 1999, Chapter 3, Section 7 and Figures 4.22 and 4.23. A person skilled in the art could, by a judicious choice of tilt angle, core radius, and core to cladding refractive index difference, limit coupling of the fundamental mode of the core into a few higher order counter-propagating modes of the core. Additionally, the tilt of the grating in a graded index multimode fibre allows the coupling of the fundament mode to a continuum of counter-propagating core modes. In this configuration, the light coupled from the light emitting source to the core of a multimode fibre can in principle be reflected into a restricted set of modes by the grating. By chirping the grating (i.e. by varying the period of the grating as a function of length) as is illustrated schematically by element 11 in

Fig. 3, it is possible to alter the bandwidth of the reflection spectrum and the choice of reflected modes. From the many modes that couple from the multimode light emitting source into the core of the multimode fibre, a selection are reflected back into the laser, forming the feedback to the light emitting source that is necessary for laser action. With the appropriate feedback (reflectivity of the grating) and good coupling to the fibre, a person skilled in the art can ensure high-power multimode operation of the laser and extract power from the output fibre end (12) of the laser, as shown in Fig. 1. It should be noted that a person skilled in the art could also propose to use other profile shapes for the refractive index of the core, for example triangular or W-profiles.

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CLAIMS

1. A laser made of semiconducting waveguide coupled to a multimode fibre with a photosensitive Bragg reflection grating in the core of the fibre, which lases in a number of modes and wavelengths determined by the properties of the fibre and grating.
2. A multi-mode laser as in Claim 1, in which the waveguide has an anti-reflection coating on the front facet and or a high reflection coating on the rear facet.
3. A multi-mode laser as in claim 2, in which the multimode fibre has a lens to allow coupling of light into the fibre from the light source.
4. A multi-mode laser as in claim 3 in which the lens is part of the multimode fibre.
5. A multi-mode laser as in claims 1 to 4, in which the grating in the multimode fibre is tilted and/or chirped or unchirped.
6. A multi-mode laser as in claims 1 to 5 in which the core of the multimode fibre is graded index, step-index, triangular or any other profile.
7. A multi-mode laser as in claims 1 to 6 in which the lasing wavelength is anywhere in the wavelength spectrum between 0.3 microns and 2 microns.
8. A multi-mode laser as in claims 1 to 7 in which the semiconductor light source is a single quantum-well or multi-quantum well or has a Fabry-Perot laser construction.

9. A multi-mode laser as in claims 1 to 8 in which it is used as a pump laser for a cladding pumped laser or amplifier.

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DRAWINGS

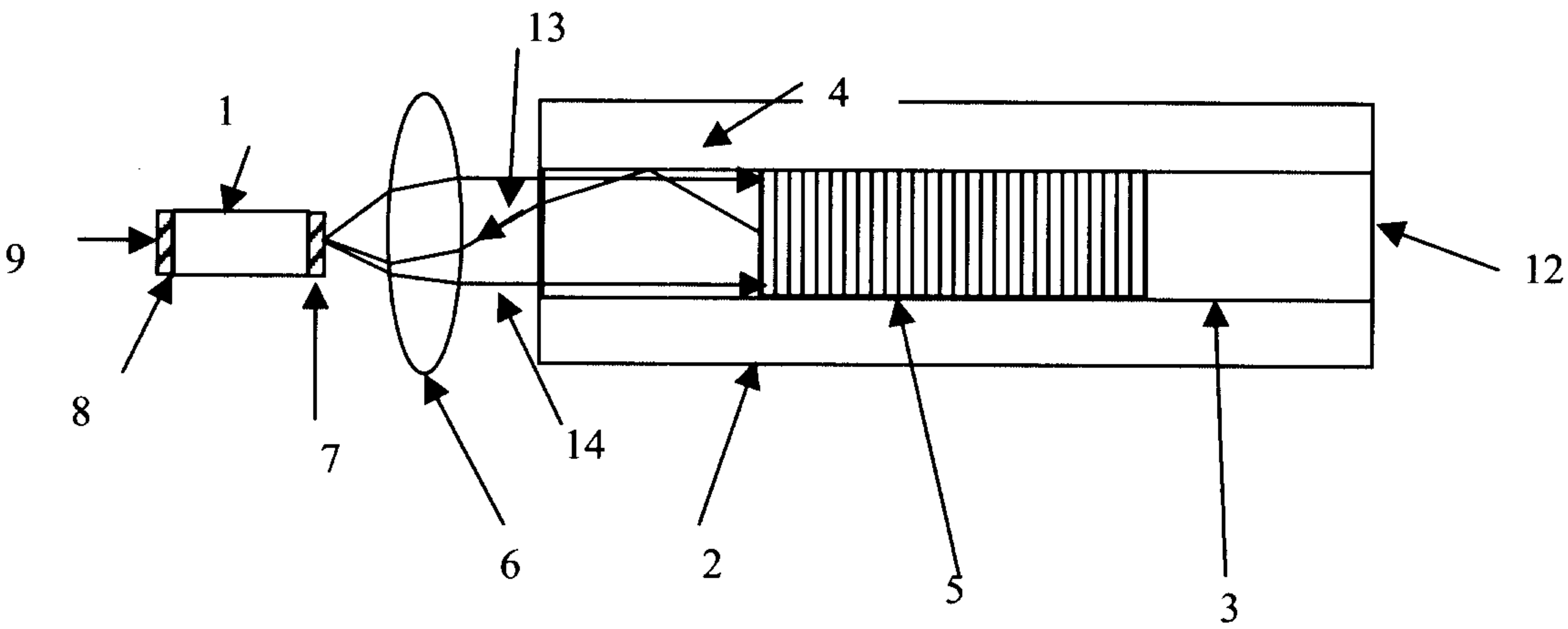

Figure 1

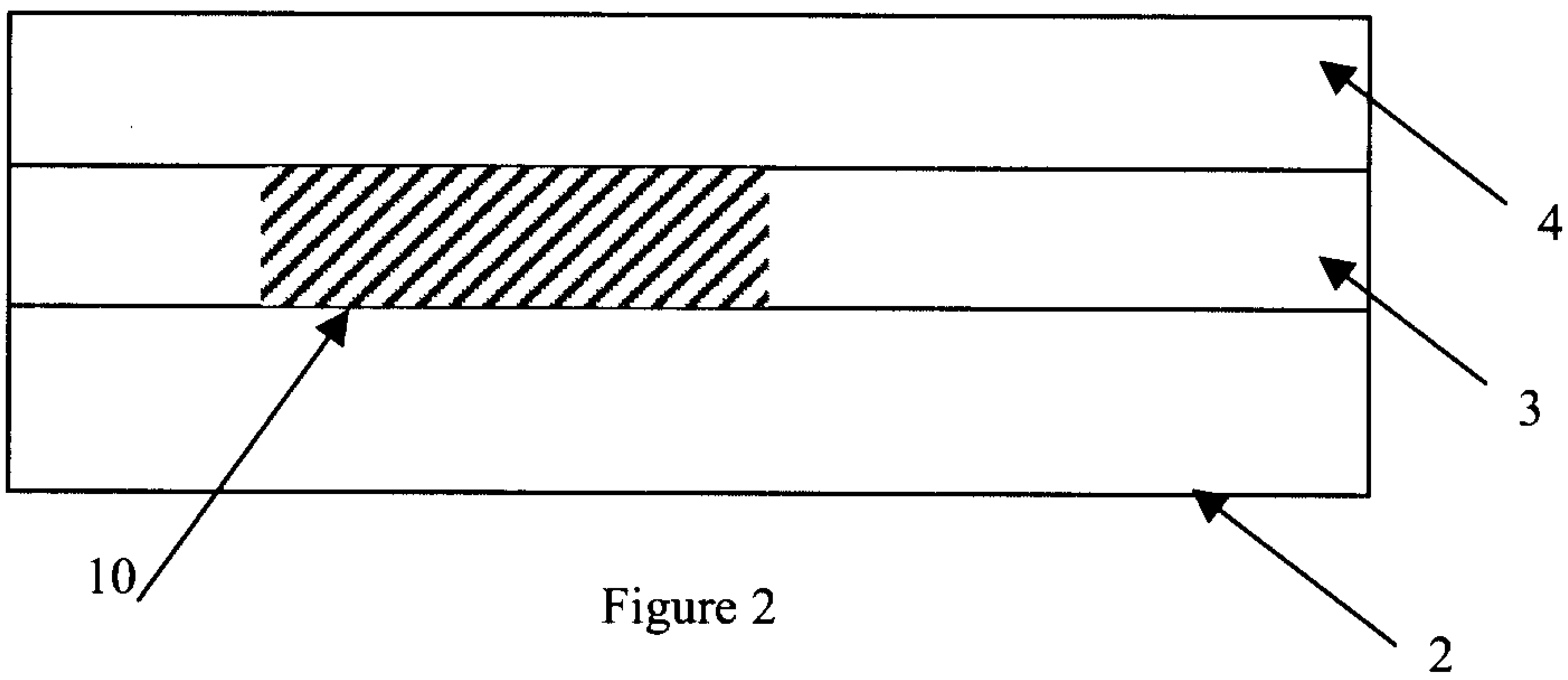

Figure 2

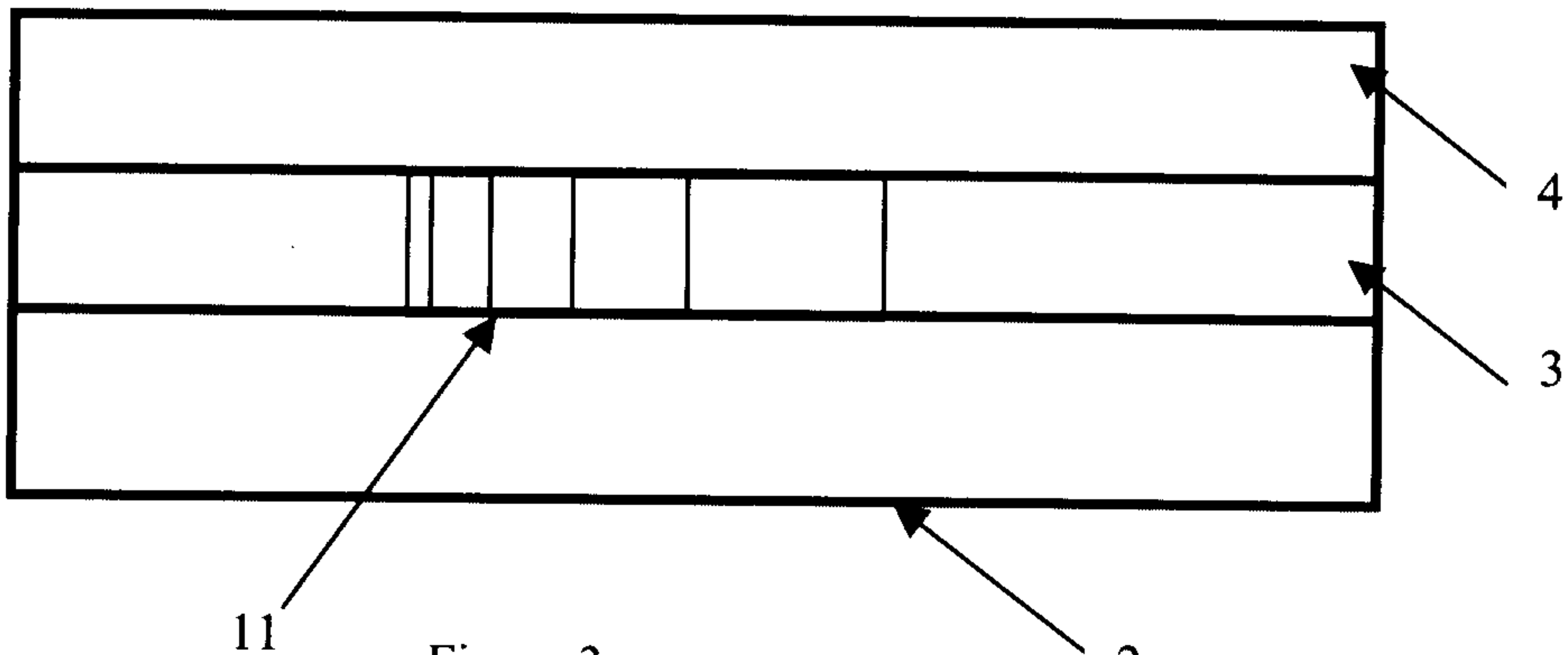

Figure 3


13
4
1
9
12
8
7
14
6
2
5
3