(12) UK Patent Application (19) GB (11) 2 180 059 (13) A

(43) Application published **18 Mar 1987**

(21) Application No **8522104**

(22) Date of filing **5 Sep 1985**

(71) Applicant
STC plc,

(Incorporated in United Kingdom),

190 Strand, London WC2R 1DU

(72) Inventor
Kevin Christopher Byron

(74) Agent and/or Address for Service
M. C. Dennis, STC Patents, Edinburgh Way, Harlow, Essex CM20 2SH

(51) INT CL[4]
G01N 21/74 G02B 6/02

(52) Domestic classification (Edition I)
G1A A1 A4 A6 G13 G7 HS P10 P6 P9 R7 S12 S4 T14 T1 T23 T3
G2J GBB1
U1S 1735 1828 1905 2159 2311 G1A G2J

(56) Documents cited

GB A 2136239	**GB 1475478**
GB A 2071351	**GB 1398645**
GB A 2061547	**US 4465334**
GB A 2044477	**US 4436368**
GB A 2035601	**US 4070091**
GB 1503793	

(58) Field of search
G1A
G2J
C1M
Selected US specifications from IPC sub-class G01N

(54) Plasma spectroscopy

(57) A remote plasma spectrometer comprises a composite optical fibre (2) via which high power pulses from a laser (1) are delivered to an article under investigation (4) and which serves also to detect photons in the plasma produced at the article and to deliver them to photon counting equipment (5) at a wavelength determined by a monochromator (6). By counting at different wavelengths a "finger print" of the article can be built up. The spectrometer is calibrated by use of known substances in place of the article (4). Fibre (2) may comprise a core (11-Figure 2) for the transmission of the laser pulses to the article, and a surrounding layer (13) for the transmission of photons from the article, a cladding layer (14). The refractive index of the core (11) is greater than that of the surrounding layer (13), which is greater than that of the cladding (14).

Fig .1.

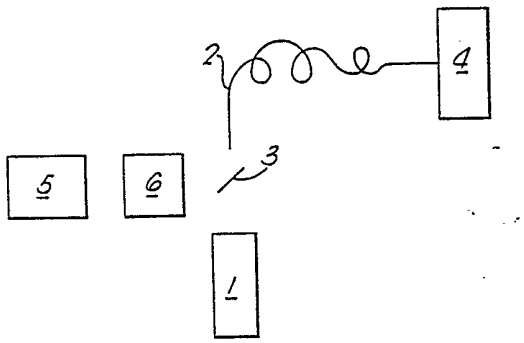
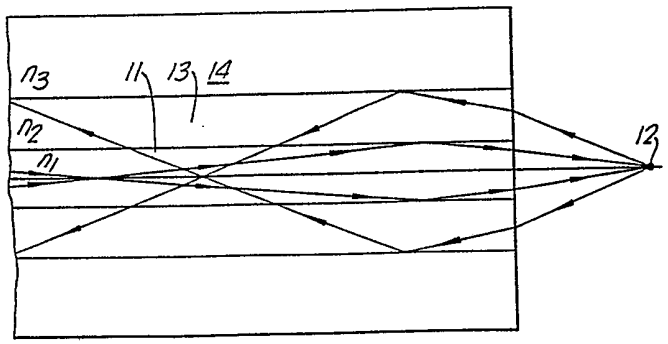


Fig .2.



GB 2 180 059 A

The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

Fig . 1.

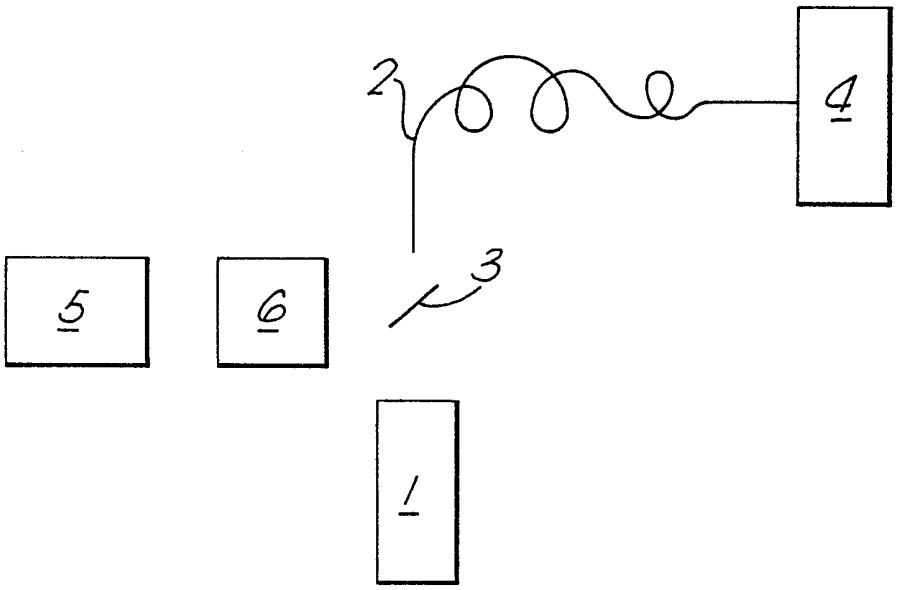
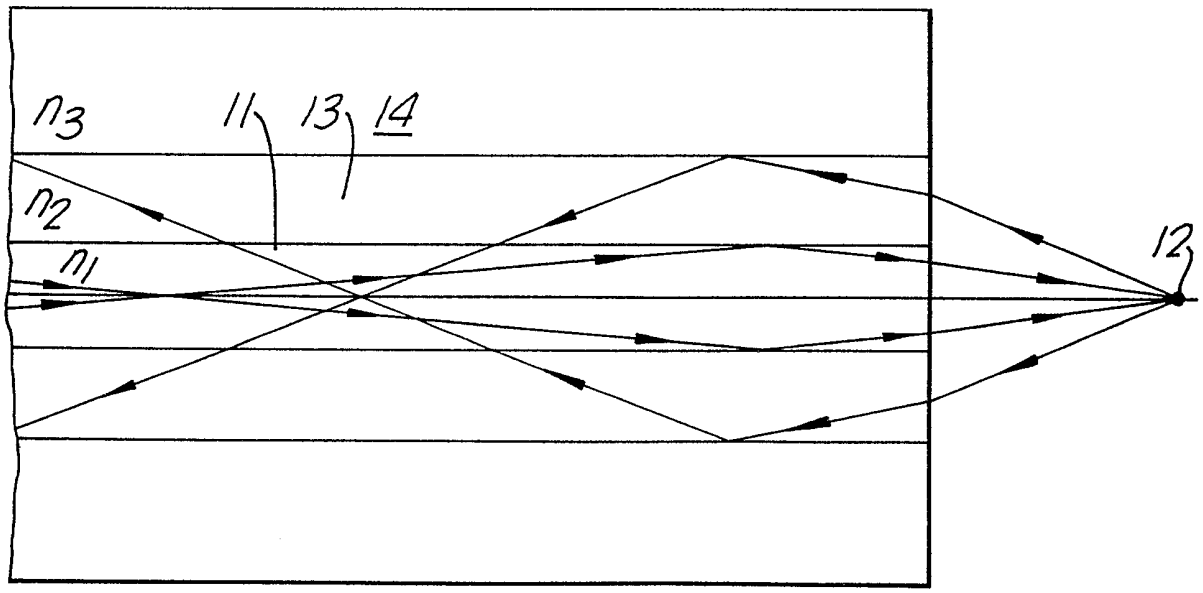


Fig . 2.



SPECIFICATION

Plasma spectroscopy

This invention relates to plasma spectroscopy and in particular to remote plasma spectroscopy.

In conventional plasma spectroscopy a high power laser pulse is caused to be incident on a material under investigation. A plasma is produced at the surface of the material and study of characteristic emission lines in the plasma allow determination of the material's constituents.

According to one aspect of the present invention there is provided a plasma spectrometer comprising a source of high power laser pulses, means to deliver the laser pulses to an article or part thereof under investigation, said means serving also to detect photons in the plasma produced at the article by the laser pulses, and means to produce an output from the detected photons indicative of the constituents of the article.

According to a further aspect of the present invention there is provided a method of investigating the constituents of an article or a part therof comprising the steps of delivering high power laser pulses to the article by way of a first means, employing the first means to detect photons in the plasma produced at the article by the laser pulses and to conduct the photons to second means whereby an output indicative of the constituents of the article is produced.

According to another aspect of the present invention there is provided a composite optical fibre, for use in remote plasma spectroscopy applications, comprising a core of a first refractive index along which laser pulses can be transmitted to an article or part thereof under investigation, a cylindrical layer, coaxial with the core and of a second refractive index, along which photons detected in a plasma produced at the article by the laser pulses can be transmitted in the opposite direction to the laser pulses, and a cladding layer of a third refractive index disposed on said cylindrical layer, the first refractive index being greater than the second refractive index, and the second refractive index being greater than the third refractive index.

According to yet another aspect of the present invention there is provided a composite optical fibre comprising a core of a first refractive index and small core cross-sectional area, a cylindrical layer coaxial with the core, the cylindrical layer being of a second refractive index with a large numerical aperture, and a cladding layer of a third refractive index disposed on said cylindrical layer, the first refractive index being greater than the second refractive index, and the second refractive index being greater than the third refractive index.

An embodiment of the invention will now be described with reference to the accompanying drawings, in which:-

Figure 1 shows schematically a remote plasma spectrometer including a composite optical fibre; and

Figure 2 shows a section through the composite optical fibre and the associated optical paths thereof.

The output of a high power laser 1 (Figure 1) for example an Nd, YAG or ruby laser is applied to one end of an optical fibre 2 via a beam splitter 3. The other end of the optical fibre is located close, for example 1mm, to an article 4 under investigation. The composite optical fibre 2 is such as to permit a laser pulse from laser 1 to be delivered to article 4 and then to simultaneously detect the spectroscopic signal in the plasma produced at the surface of the article and transmit it to a photon counting system 5 via the beam splitter 3. A monochromator 6 serves to tune the detected spectroscopic signal to a particular wavelength so that the system 5 can count the photons at that particular wavelength. By counting photons at various different wavelengths a "finger print" of low level impurities etc in the article 4 can be obtained. The spectroscope is calibrated by use of known substances in the place of article 4.

The plasma is produced without the necessity for lenses merely by bringing the fibre end close to the material under test. The laser and photon counting equipment can be disposed at a position remote from the material under test due to the use of a fibre to deliver the laser pulse to the material and to detect the photon output, which fibre effectively comprises a probe which may be positioned in relatively inaccessible places to test material thereat. Typical applications of plasma spectroscopy include corrosion detection in reactors, tanks etc, archeological investigations and forensic testing. The remote plasma spectrometer employs an essentially non-destructive technique since only a small pit of a few microns depth and width is produced.

The basic requirements of the single composite fibre 2 are the ability to transmit laser light with a high power density and the provision of a suitable collection area for the returning spectroscopic signal. A suitable coaxial fibre design comprises a core with a small cross-sectional area for transmitting the laser light and a surrounding cylindrical layer with a large numerical aperture (N.A.) and providing a large collection area. Such an arrangement is shown in Figure 2 and comprises a core 11 for the transmission of laser light to a point 12, for the generation thereat of a plasma, a cylindrical layer 13 for the return path for photons detected in the plasma at point 12 and a cladding layer 14. The refractive index n_1 of the core 11 is greater than the refractive index n_2 of the layer 13 which is greater than the refractive index n_3 of the cladding layer 14 ($n_1 > n_2 > n_3$).

The core 11 may be of highly doped GeO_2 or pure GeO_2, the layer 13 may be of moderately doped GeO_2, and the cladding layer 14 may be of pure SiO_2. Further protective layers may be applied to layer 14 as required. Typically the radius of core 11 is of the order of 5 to 50μm whereas the outer radius of layer 13 is of the order of 50 to 200μm. In the case of plasma spectroscopy applications the transmission loss for the core 11 is unimportant since high powers over relatively short fibre lengths are concerned. However the return path, layer 13, should be as low in attenuation as possible in order to obtain the maximum transmitted signal from the plasma at point 12.

CLAIMS

1. A plasma spectrometer comprising a source of high power laser pulses, means to deliver the laser pulses to an article or part thereof under investigation, said means serving also to detect photons in the plasma produced at the article by the laser pulses, and means to produce an output from the detected photons indicative of the constituents of the article.

2. A plasma spectrometer as claimed in claim 1 wherein the means to deliver the laser pulses and to detect the photons comprises a composite optical fibre.

3. A plasma spectrometer as claimed in claim 1 or claim 2 wherein said output producing means comprises a photon counting arrangement and a monochromator whereby to enable counting of photons at predetermined wavelengths.

4. A plasma spectrometer substantially as herein described with reference to and as illustrated in Figure 1 with or without reference to Figure 2 of the accompanying drawings.

5. A method of investigating the constituents of an article or a part thereof comprising the steps of delivering high power laser pulses to the article by way of a first means, employing the first means to detect photons in the plasma produced at the article by the laser pulses and to conduct the photons to second means whereby an output indicative of the constituents of the article is produced.

6. A method as claimed in claim 5 wherein the first means is a composite optical fibre.

7. A method as claimed in claim 5 or claim 6 wherein the second means comprises a photon counting arrangement and a monochrometer and including the steps of setting the monochromator to a respective particular wavelengths and counting the numbers of photons thereat.

8. A method of investigating the constituents of an article or a part thereof substantially as herein described with reference to Figure 1 with or without reference to Figure 2 of the accompanying drawings.

9. A composite optical fibre, for use in remote plasma spectroscopy applications, comprising a core of a first refractive index along which laser pulses can be transmitted to an article or part thereof under investigation, a cylindrical layer, coaxial with the core and of a second refractive index, along which photons detected in a plasma produced at the article by the laser pulses can be transmitted in the opposite direction to the laser pulses and a cladding layer of a third refractive index disposed on said cylindrical layer, the first refractive index being greater than the second refractive index, and the second refractive index being greater than the third refractive index.

10. A composite optical fibre as claimed in claim 9, wherein the core is of highly doped of pure GeO_2, the cylindrical layer is of moderately doped GeO_2 and the cladding is of pure SiO_2.

11. A composite optical fibre substantially as herein described with reference to Figure 2 of the accompanying drawings.

12. A composite optical fibre comprising a core of a first refractive index and small core cross-sectional area, a cylindrical layer coaxial with the core, the cylindrical layer being of a second refractive index with a large numerical aperture, and a cladding layer of a third refractive index disposed on said cylindrical layer, the first refractive index being greater than the second refractive index, and the second refractive index being greater than the third refractive index.

Printed for Her Majesty's Stationery Office by
Croydon Printing Company (UK) Ltd, 1/87, D8817356.
Published by The Patent Office, 25 Southampton Buildings, London WC2A 1AY, from which copies may be obtained.