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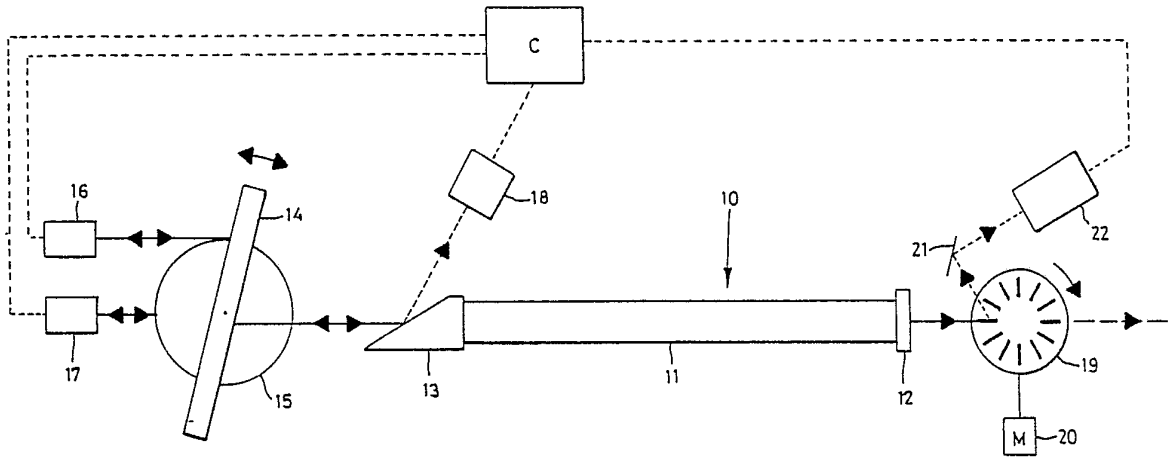
(54) Title: COMPUTER CONTROLLED TUNING OF LASERS



(57) Abstract

A laser (10) of the type having a cavity (11), front window (12) and Brewster window (13) is tuned to its characteristic lines in its gain envelope by the angular rotational and/or longitudinal movement of grating (14) relative to the cavity axis. The grating (14) is mounted on a turn-table (15) and the angular and longitudinal position of the grating (14) is tuned to one of its characteristic lines as determined by the detector (18). The photoacoustic cell (22) receives a portion of the output beam of the laser (10) and from the absorption characteristics of the gas in the photoacousting cell (22), the identity of the characteristic line of the laser (1) can be determined, together with the corresponding position of the grating (14) for that line.

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Title: "COMPUTER CONTROLLED TUNING OF LASERS"

BACKGROUND OF THE INVENTION

(1) Field of the Invention

THIS INVENTION relates to a method of, and apparatus for, computer controlled tuning of lasers.

(2) Prior Art

In recent years, the range of applications for lasers has increased markedly. In industry, lasers are used in areas such as cutting, welding, surveying and gas analysis, while in medicine, they are used as scalpels and for welding detached retinas.

One major problem has been to accurately tune the lasers to operate at selected frequencies (or wavelengths), each laser having a characteristic set of lines within its gain envelope. For example, it has not been possible to accurately tune CO_2 type lasers at all of the characteristic lines in their gain envelope. Generally each laser has been set to operate at a fixed wavelength.

It is well known that different gases absorb light at different wavelengths in characteristic patterns which provide a "signature" for the gases. These patterns enable the existence and/or concentration of the gases to be detected e.g. for leak detection purposes in factories.

Where a gas has to be tested at two or more wavelengths, two or more accurately tuned, highly stabilized lasers must be employed, each tuned to a particular wavelength. The equipment must be highly stabilized as variations in temperature and pressure can change the wavelength of the laser light. The change in wavelength may be such that the lasers operate at characteristic lines other than for which they are allegedly tuned and so false qualitative and/or quantitative measurements may be made in relation to the gas.

The equipment necessary to maintain the stability of the lasers prevents them from being readily portable or versatile and so has restricted the range of potential industrial applications.

SUMMARY OF THE PRESENT INVENTION

It is an object of the present invention to provide computer controlled tuning for lasers where the lines in the gain envelope can be identified.

It is a preferred object to provide such tuning which enables the laser to be tuned to selected lines.

It is a further preferred object to provide such tuning where the whole system is temperature independent and self-correcting.

Other preferred objects of the present invention will become apparent from the following description.

In one aspect the present invention resides in a method for tuning a laser of the type having a cavity, a front window, a Brewster window and a grating, the method including the steps of:

(a) mounting the grating on a mounting movable relative to the cavity;

(b) moving the grating to a selected angular position and/or cavity length relative to the cavity;

(c) measuring the laser power output using a first detector and moving the grating to optimise the laser power output so that the laser is tuned to a characteristic line;

(d) measuring the angular position and cavity length of the grating corresponding to the characteristic line;

(e) measuring the output from a photoacoustic cell or second detector located in at least a portion of the output beam from the laser;

(f) repeating steps (b) to (e) until the gain

envelope of the laser has been traversed; and

(g) from the measurements in step (3), establish the identity of each line sampled in the gain envelope and its respective grating position.

In a second aspect the present invention resides in an apparatus for tuning a laser of the type comprising a cavity, a front window, a Brewster window and a grating, the apparatus including:

a mounting for the grating movable to vary the angular position and the cavity length of the grating relative to the cavity;

means to move the mounting;

a first detector to measure the power output from the laser;

a photoacoustic cell or second detector located in at least a portion of the output beam from the laser;

means to measure the output from the photo-acoustic cell or second detector; and

means to control the movement of the mounting, and thereby the grating, dependent on the measurement of the output power of the laser by the first detector and the measured output of the photoacoustic cell or second detector.

Preferably the laser grating is mounted on a turn-table rotatable (e.g. by a stepping motor) to vary the angular position of the grating relative to the cavity axis, the turn-table being longitudinally movable (e.g. by a piezoelectric drive) along, or parallel to the cavity axis to vary the cavity length.

Preferably, in step (c), the output from the laser is measured by a first detector which registers the intensity of the beam reflected from the Brewster window in the laser tube.

Preferably a beam chopper-splitter is provided

outside the cavity, spaced from the front window, to provide a chopped output beam at the laser frequency and proportional to its power. Preferably the beam reflected by the chopper-splitter is reflected by a mirror onto a photoacoustic cell (containing e.g. ammonia or ethylene) to measure the laser output in step (e).

Preferably the system is controlled by a computer/microprocessor capable of driving the stepping motor, the piezoelectric driver and registering the outputs from the detector and the photoacoustic cell. Suitable software is provided to control the system.

BRIEF DESCRIPTION OF THE DRAWINGS

To enable the invention to be fully understood, a preferred embodiment will now be described with reference to the accompanying drawings, in which:

FIG. 1 is a schematic layout of the control system;

FIG. 2 is a graph of the CO_2 laser gain curve; and

FIG. 3 is a graph of the absorption characteristic of ammonia relative to the lines of the CO_2 gain curve.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIG. 1, the laser 10 has a cavity 11 with a front window 12 and a Brewster window 13.

The grating 14 is mounted on a turn-table 15 which is rotatable by a micrometer driven by a stepping motor 16 to vary the grating angle and which is movable along (or parallel to) the cavity axis, to vary the cavity length, by a piezoelectric device 17.

The laser power output is monitored by a detector 18 which registers the intensity of the beam reflected from the back of the Brewster window 13.

A beam chopper-splitter 19 is provided in front of the front window 12 and is driven by a motor 20. The face of the chopper-splitter 19 is mirrored to reflect a chopped output beam to a mirror 21, which reflects the beam to a photoacoustic cell 22 containing e.g. ammonia or ethylene at a low partial pressure to to calibrate the frequency (or wavelength) of the particular line.

The stepping motor 16, piezoelectric device 17, detector 18 and photoacoustic cell 22 are connected to a computer or micropressor C.

The software in the computer C causes the stepping motor 16 to drive the grating 14 to a selected angular position and then varies the cavity length (via the piezoelectric device 17).

By monitoring the laser power via detector 18, the grating position can be optimised for a particular laser characteristic line.

The output from the photoacoustic cell 22 is monitored and the steps are repeated until the gain envelope of the laser (FIG. 2) has been traversed.

By using the measurings obtained by the above steps, and by reference to the known absorption coefficients of the gas in the photoacoustic cell 22, the identity of each characteristic line in the gain envelope can be established for reference against the respective grating angle and cavity length therefor.

Should an operator wish to measure the absorption coefficient of a gas at a line e.g. identified as P10, he can type the line identification into the computer and the computer will operate the stepping motor 16 and piezoelectric drive 17 to position the grating 14 to so tune the laser to that line. To check that the laser is tuned at line P10, the operator can move the grating to tune the laser to line P6 where high

absorption of the light occurs in the photoacoustic cell and then move the grating back towards its initial position, traversing 4 characteristic lines. Turning the laser to line P12 and then returning the grating to its initial position provides a confirmatory check that the laser is tuned to line P10 as required.

In the graph of FIG. 3, high absorption of the light in the ammonia occurs near lines P12, P18 and P38 and low absorption at lines P30 and P40. By measuring the relative absorption at each file line of the CO_2 laser, a fingerprint would establish the presence of ammonia while the differential absorption at say lines P18 and P30 would establish the concentration of the ammonia.

While the present invention can have particular application for low power, low gain short cavity lasers, the computer controlled tuning method and apparatus is suitable for most, if not all, types of lasers and provides a compact, stable and efficient tuning facility.

Various changes and modifications may be made to the embodiment described without departing from the scope of the present invention as defined in the appended claims.

CLAIMS

1. A method for tuning a laser of the type having a cavity, a front window, a Brewster window and a grating, the method including the steps of:

(a) mounting the grating on a mounting movable relative to the cavity;

(b) moving the grating to a selected angular position and/or cavity length relative to the cavity;

(c) measuring the laser power output using a first detector and moving the grating to optimise the laser power output so that the laser is tuned to a characteristic line;

(d) measuring the angular position and cavity length of the grating corresponding to the characteristic line;

(e) measuring the output from a photoacoustic cell or second detector located in at least a portion of the output beam from the laser;

(f) repeating steps (b) to (e) until the gain envelope of the laser has been traversed; and

(g) from the measurements in step (3), establish the identity of each line sampled in the gain envelope and its respective grating position.

2. A method as claimed in Claim 1 wherein:

the mounting for the grating includes a turntable rotatable to vary the angular position of the grating relative to the cavity axis and longitudinally movable along, or parallel to, the cavity axis to vary the cavity length.

3. A method as claimed in Claim 1 wherein:

the first detector measures the intensity of teh beam reflected from the Brewster window, the laser output power being proportioned to the reflected beam.

4. A method as claimed in Claim 1 wherein:

a beam chopper-splitter is provided outside the cavity, spaced from the front window, to provide a chopped output beam, proportional to the output power of the

laser, to the photoacoustic cell.

5. A method as claimed in Claim 1 wherein:

a computer is operably connected to move the mounting dependent on the laser power output measured by the first detector and the output of the photoacoustic cell or second detector.

6. Apparatus for tuning a laser of the type comprising a cavity, a front window, a Brewster window and a grating, the apparatus including:

a mounting for the grating movable to vary the angular position and the cavity length of the grating relative to the cavity;

means to move the mounting;

a first detector to measure the power output from the laser;

a photoacoustic cell or second detector located in at least a portion of the output beam from the laser;

means to measure the output from the photoacoustic cell or second detector; and

means to control the movement of the mounting and thereby the grating, dependent on the measurement of the output power of the laser by the first detector and the measured output of the photoacoustic cell or second detector.

7. Apparatus as claimed in Claim 6 wherein:

the mounting for the grating includes a turntable rotatable to vary the angular position of the grating relative to the cavity axis and longitudinally movable along, or parallel to, the cavity axis to vary the cavity length.

8. Apparatus as claimed in Claim 6 wherein:

the first detector measures the intensity of the beam reflected from the Brewster window, the laser output power being proportioned to the reflected beam.

9. Apparatus as claimed in Claim 6 wherein:

a beam chopper-splitter is provided outside

the cavity, spaced from the front window, to provide a chopped output beam, proportional to the output power of the laser, to the photoacoustic cell.

10. Apparatus as claimed in Claim 6 wherein:

a computer is operably connected to move the mounting dependent on the laser power output measured by the first detector and the output of the photoacoustic cell or second detector.

11. A laser tuned by the method claimed in Claim 1.

12. A laser tuned by the apparatus claimed in Claim 6.

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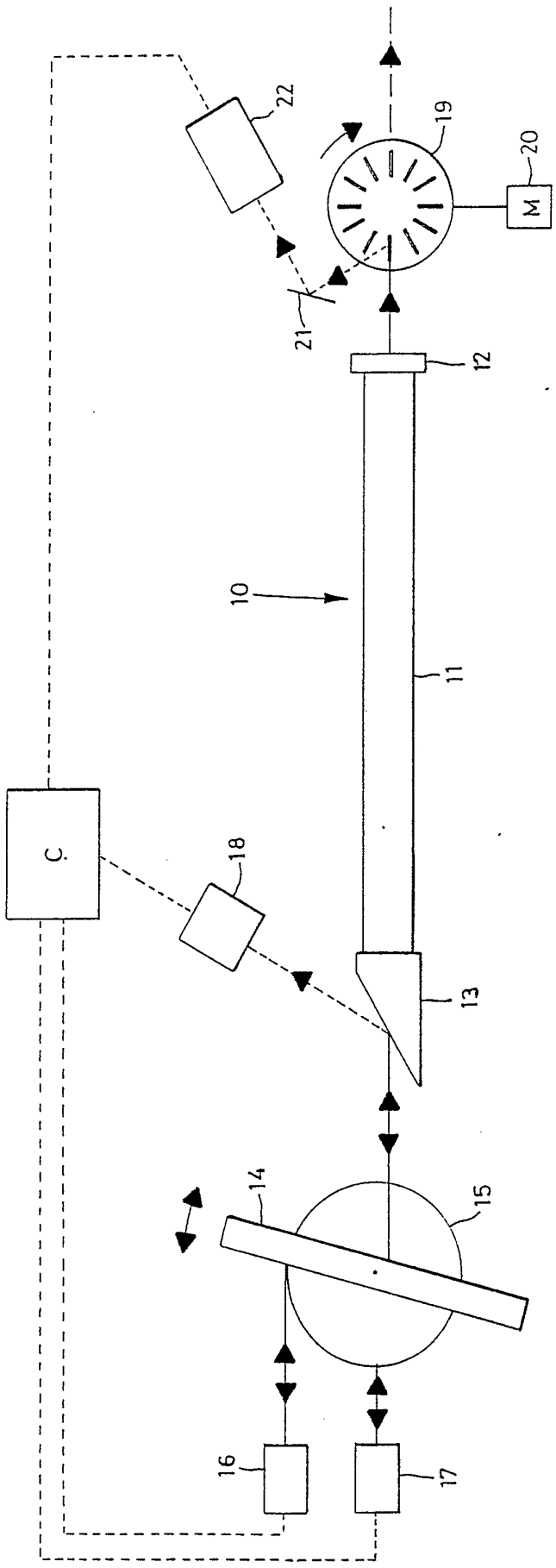

FIG. 1

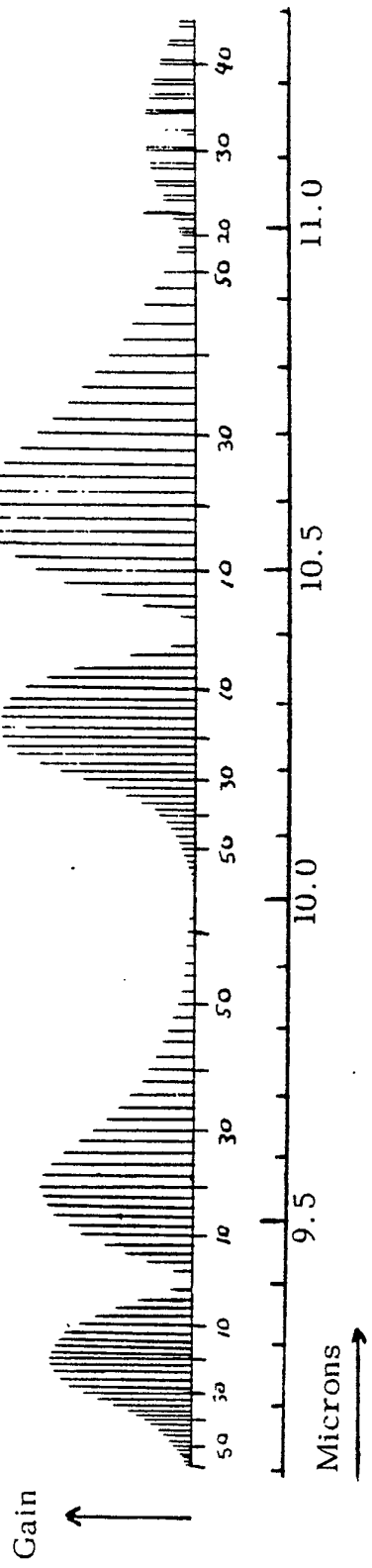

FIG. 2 - CO_2 Laser Gain Curve

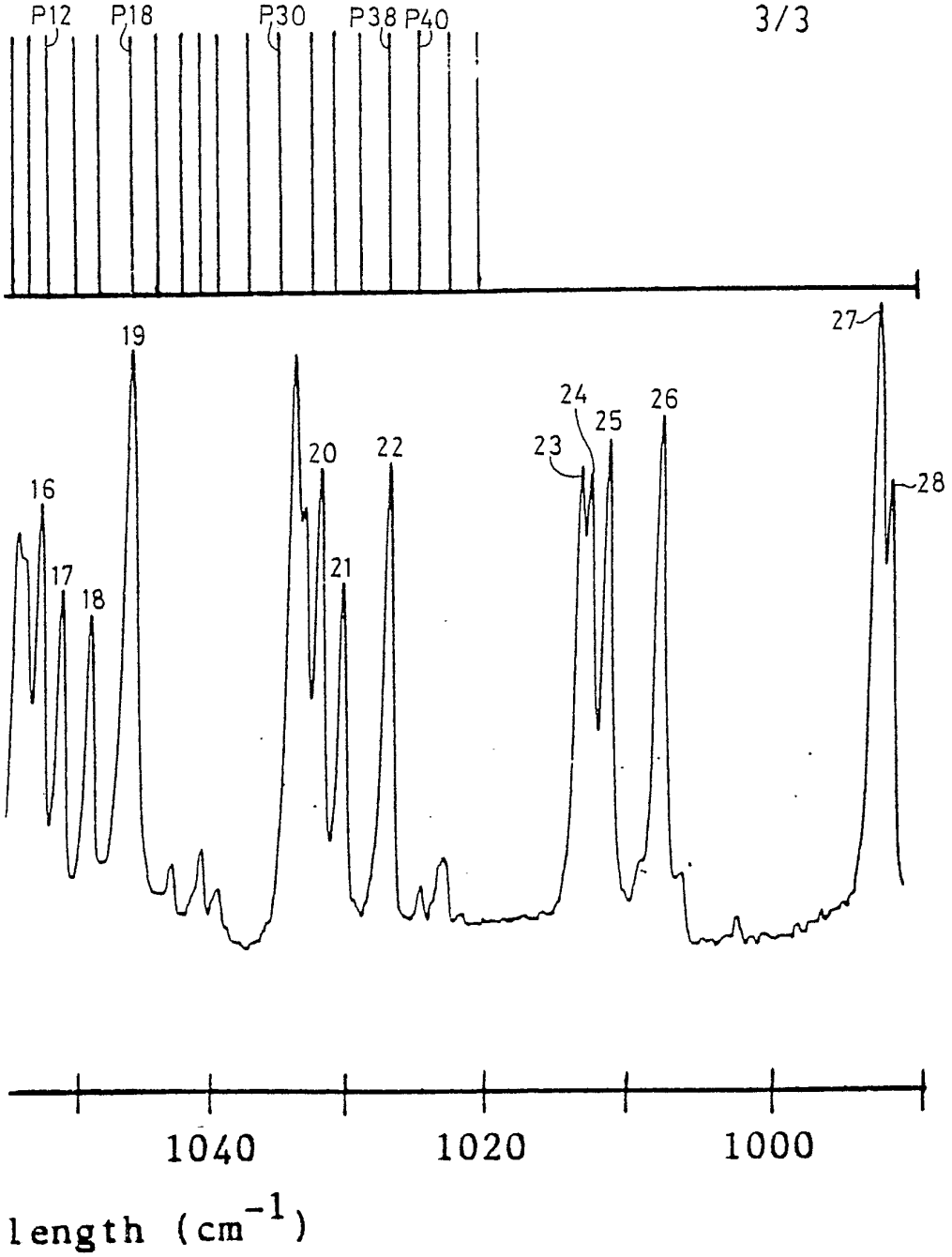
P12
P18
P30
P38
P40
16
17
18
19
20
21
22
23
24
25
26
27
28
1040
1020
1000
length (cm^{-1})

FIG. 3

INTERNATIONAL SEARCH REPORT

International Application No PCT/AU 86/00026

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [6]

According to International Patent Classification (IPC) or to both National Classification and IPC

Int. Cl.[4] H01S 3/1055

II. FIELDS SEARCHED

Minimum Documentation Searched [7]

Classification System	Classification Symbols
IPC	H01S 3/10, 3/1055

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [8]

AU; IPC as above

III. DOCUMENTS CONSIDERED TO BE RELEVANT [9]

Category *	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No. [13]
A	AU,B, 66607/81 (537265) (EERKENS) 30 April 1981 (30.04.81)	
A	GB,A, 1494062 (ALLIED CHEMICAL CORPORATION) 7 December 1977 (07.12.77)	
A	US,A, 4150342 (JOHNSTON et al) 17 April 1979 (17.04.79)	

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IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
22 April 1986 (22.04.86)	(07-05-86) 7 MAY 1986
International Searching Authority	**Signature of Authorized Officer**
Australian Patent Office	N.C. PETERSEN

Form PCT/ISA/210 (second sheet) (January 1985)

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON

INTERNATIONAL APPLICATION NO. PCT/AU 86/00026

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report	Patent Family Members		
AU 66607/81	AU 20106/76	BR 7608290	CA 1071139
	DE 2656152	FR 2334407	GB 1573507
	IL 51038	JP 52093897	NL 7613767
	US 4082633		
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