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MANUAL FOR RAMAN CELLS

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W. Mueckenheim

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16. Abstract

Characteristics of Raman cells offered by Lambda Physik are described, assembly and installation instructions are given, and conversion from one variant to another is described.

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MANUAL FOR RAMAN CELLS

W. Mueckenheim

1. Safety Instructions /*

1.1. The Raman cells emit intense laser pulses from the ultraviolet to the infrared spectral region, which can lead to eye damage and skin injuries. Avoid looking directly at laser radiation and do not allow it to fall on the skin. Take note that when the case is opened, several laser beams can emerge, which diverge in space. We are dealing with various Raman lines here. The reflections from light-scattering objects can also be dangerous to the health. You and the persons in the laboratory should wear goggles for the emitted spectral range.

1.2. In the adjustment operate the pump laser with the minimum possible outlet energy.

1.3. The Raman cell is operated with combustibles and explosive gases under high pressure. An overpressure valve, which responds at 40 bar, protects the Raman cell from too high pressure. The waste gas holes must therefore end outside the building or in a discharge. The holes of the gas cylinder to the Raman cell must be made of copper (40 bar!). Before allowing the pump beam to enter the Raman cell, rinse the cell 3-5 times with hydrogen, so that no residual oxygen remains in the cell, which would lead to an explosive mixture.

2. Physical Mode of Operation /

The Raman cell is based on the principle of stimulated Raman scattering (SRS). In this context a molecular system (for example H_2) is excited with a pump laser (for example excimer or dye laser) from an initial state N_A into a virtual state N_V. If the pump intensity is large enough to achieve a level of occupation

*Pages in original text are unnumbered; a slash (/) in the margin indicates a new page in the original text.

between the virtual level N_V and a lower-lying final level N_E, stimulated emission starts.

If the starting level N_A lies at a lower energy than the final level N_E, the stimulated Raman level is shifted towards the red as compared with the pump wave (Fig. 1a). The frequency of this first Stokes line (S) is obtained as:

$$\omega_{-1} \doteq \omega_0 - \frac{E_E - E_A}{\hbar} = \omega_0 - \omega_{EA}$$

ω_0 = frequency of the pump wave; E_A = energy of the initial level; E_E = energy of the final level.

This process can be repeated starting from the level N_E, which is indeed occupied by the stimulated emission. If the initial frequency ω_0 is calculated on N_E, the first anti-Stokes line (AS_1) arises. It is shifted towards the blue as compared with the pump wave, and its frequency is given by:

$$\omega_1 = 2\omega_0 - \omega_{-1} = \omega_0 + \omega_{EA}$$

In this way, an entire sequence of anti-Stokes lines are generated successively with the frequencies ω_n (Fig. 1b):

$$\omega_n = \omega_0 + n\,\omega_{EA} \quad n = 1,2,3 \ldots$$

Higher Stokes lines occur either through a repeated direct Stokes process according to Fig. 1a

$$\omega_{-n} = \omega_{-n+1} - \omega_{EA}$$

or also by resonant interaction between S_1, pump wave and other higher Stokes lines (Fig 1c)

$$\omega_{-n} = \omega_{-1} + \omega_{-n+1} - \omega_0 = \omega_0 - n\,\omega_{EA}$$

Hydrogen, with its low dispersion and its high energy distance of the vibronic level is particularly suitable, since it also has a large Raman cross section.

A shift of 4155 cm^{-1} for the transition from the state $\nu = 0$, $J = 1$ to the state $\nu = 1$, $J = 1$ is determined. Thus frequencies of the other Raman lines are established. It is apparent from Fig. 2 which wavelengths are available as a function of the pump wave.

Through the simulated Raman scattering in hydrogen it is therefore possible to generate laser radiation from the vacuum-ultraviolet (VUV) up to the far infrared (FIR). Since we are dealing with a nonlinear effect, high pump power densities (about 100 MW/cm^3) are needed. This may be achieved by focusing of the pump beam.

The intensity of individual lines depends on the density of hydrogen (key word: "phase matching"; see literature for details). For each line there is an optimal pressure. For the first Stokes lines thus a conversion efficiency of at most 50% may be achieved. The intensity decreases with the order of the line, since we are dealing with many-photon processes.

REFERENCES

Brink, D.J., D. Proch, D. Basting, K. Hohla, and P. Lokai, "Raman frequency shifting: A simple efficient way to VUV and IR generation," Laser and Optoelektronik 3 (1982).

Brink, D.J. and D. Proch, "An efficient tunable UV-source based on stimulated Raman scattering of an excimer-pumped dye laser," Opt. Lett. (1982).

Komine, H., E.A. Stappaerts, S.J. Brosnan, and J.B. West, Appl. Phys. Lett. 40, 551-553 (1982).

Wilke, V. and W. Schmidt, "Tunable coherent radiation source covering a spectral range from 185 to 880 nm," Appl. Phys. 18, 177-181 (1979).

3. Structure of the Raman Cell

Lambda Physics offers six different variants of the Raman cell. They differ in spectral range and in the pump laser used:

1. RS 75-1500 D: 190-1500 nm, dye laser,
2. RS 75-700 E: 190-700 nm, excimer laser,
3. RS 75-140 D: 140-1500 nm, dye laser,
4. RS 75-140 E: 140-700 nm, excimer laser,
5. RS 75-4500 D: 600-4500 nm, dye laser,
6. RS 75-9000 D: 900-9000 nm, dye laser.

From Table 4 in the Appendix and the corresponding comments, you may see the components constituting the different variants.

3.1. Type 1: RS 75-1500 D and RS 75-1500 E

Figure 3 shows the basic structure of these two Raman cells.

The mirrors S_1, S_2 deflect the pump beam into the high pressure tube HDR, which is filled with hydrogen gas. The lens L_1 focuses the pump beam and is used simultaneously as input window for the HDR. The focus of L_1 is approximately at the center of the HDR. Thereafter the diverging beams are focused with the lens L_2 (also acting simultaneously as window) through the two prisms P_1 and P_2 on slit Sp_1 which is used to block out the undesired Raman lines.

Prism P_1 is the frequency-selecting element of the optical system. Here we have a quartz Pellin-Broca prism. The advantage of this prism is that it has a constant deflection of 90^o at maximum dispersion. The adjustment takes place through simple rotation of the prism around the axis shown in Fig. 3.

P_2, a 90^o prism, reflects the beams back in parallel to the optical axis of the Raman cell. Lens L_3 can be used for the purpose of forming images. The beam enters through a closable opening in the front of the Raman cell. Lens L_3 and slit Sp_1

can be shifted on a joint carrier, since the focal points for the individual anti-Stokes and Stokes lines line at different points.

All optical components for the wavelength range from 0.19 μm to 1.5 μm are of quartz.

The Raman cell RS 75-1500 D is pumped with a dye laser, the RS 75-700 E variant with an excimer laser. The following differences exist in the equipment:

1) RS 75-700 E:

Deflecting mirror S_1, S_2

TABLE 1

ArF:	2 x 45/193 nm
KrF:	2 x 45/248 nm
XeCl:	2 x 45/308 nm
XeF:	2 x 45/351 nm

Extensions K

Since for the short wavelengths of excimer radiation, the index of refraction of quartz and therefore the focal distance of the input lens L_1 varies strongly with the frequency, the focus shift must be compensated by an intermediate element K (see Fig. 3). They are incorporated between the lens L_1 and the HDR (see Section 5.1).

There are two intermediate elements A and B of different thickness for this purpose. The following combinations must be introduced:

TABLE 2

	A	B
λ = 193 nm	-	-
λ = 248 nm	1	1
λ = 308 nm	1	2
λ = 351 nm	1	3

Coupling tube R (see Fig. 10)

The 335-mm long tube is needed for the excimer laser.

Prisms P_1, P_2

Their dimensions make it possible to cover the entire excimer beam.

2) RS 75-1500 D

Deflection mirror S_1, S_2

2x three-times vaporized mirrors for spectral ranges:

TABLE 3

IR	610-860 nm
VIS	420-650 nm
UV	320-450 nm

K Extensions

With a dye laser as pumping source, no intermediate elements are needed, since at these pump frequencies, no noticeable change occurs for the index of refraction.

Coupling tube R

The 185-mm long tube is used.

Prisms P_1, P_2

They may be smaller because of the small beam diameter of the dye laser.

3.2. Type 2: RS 75-140 D and RS 75-140 E

The cell RS 75-140 D is provided for dye laser operation, the RS 75-140 E variant for excimer laser operation. The Raman cells of Type 2 differ from those of Type 1 only in the parts concerning the excited Raman scattering. Two factors must be taken into consideration:

* For the indicated spectral range, only MgF_2 may be used as the material for the optical components. The index of refraction of MgF_2 is very small in this range ($\sim$1). For this reason, the lenses must be very strongly curved, and the prisms are inconveniently large.

* The VUV radiation is absorbed to a considerable extent by air, so that the beam paths for the Raman lines must be evacuated or must be rinsed with an inert gas.

For these reasons the outlet window W_1 is on a parallel plane MgF_2 disk (see Fig. 4). Then follows a vacuum flange to which the experiment may be connected. If you are interested in further optical systems for this wavelength range, please contact Lambda Physik.

Otherwise, the same applies for the differences between the excimer and dye laser pumped variants as for Type 1, except for prisms, which are not needed here.

3.3. Type 3: RS 75-4500 D and RS 75-9000 D

For these Raman cells a dye laser is used as pump source, since its wavelength makes it possible to cover the given range with Raman lines of relatively small order. With an excimer laser the orders of the required Raman lines would be so large that it would not be possible to expect any noticeable intensities.

For this type of Raman cell an optical waveguide is also used. It increases through a lower progressive speed of the electromagnetic waves, its time of interaction and thus it increases the efficiency of the Raman effect. To obtain a high degree of coupling and decoupling and therefore a high transmission of the waveguide, the dye laser should be adjusted to achieve good beam quality, low divergence and homogeneous beam profile.

Three-times vaporized mirrors are used as deflecting mirrors S_1, S_2. The focusing of the pump wave is achieved with an external quartz lens L_1 (see Fig. 5) with AR coating and a focal distance f = 300 mm; it is attached with a lens holder with fine adjustment in the holes provided between HDR and S_2 in the case wall (Fig. 15).

The input window W_1 is an 8-mm thick parallel plane quartz disk. A 650-mm long quartz capillary tube is provided in the HDR as waveguide. The focus of L_1 lies at the beginning of the hole of the quartz capillary.

The outlet window W_2 consists of an 8-mm thick CaF_2 disk, which allows wavelengths up to 9 μm to pass through. The prisms P_1 and P_2 are of standard IR glass, which can be used up to 5 μm (RS 75-4500 D). For a range extension up to 9 μm, Lambda Physik supplies prisms of CaF_2 (RS 75-9000 D). Lens L_2 (f = 300 mm) of IR glass or CaF_2 can be used for purposes of image formation. The undesired Raman lines are blocked out with the diaphragm Sp_1.

3.4. Gas Manipulation

In all variants of the Raman cell, the structure of the gas supply system according to Fig. 6 is the same.

To control the hydrogen-filling process, the three-way ball valve is used with the positions "closed," "fill," and "exhaust," as well as manometer M which indicates the pressure in the cell. Safety valve SV responds at a pressure p = 40 bar and discharges the overpressure into the waste-gas lines which are connected at the connection (left of the three-way valve) to the Raman cell and must lead into the open air or a discharge. The filling connection is located on the right-hand side of the three-way valve.

4. Installation

4.1. Delivery Schedule

1 Raman cell

1 2.5 m x 6 mm copper tube with two connections

1 10 m x 6 mm plastic hose with one connection

2 adjusting devices

4.2. Additionally Required Materials

To operate the Raman cell on a Lambda Physik laser (excimer or dye laser) you will also need a gas cylinder with 99.9999% (6.0) hydrogen as well as a high pressure regulation valve up to 40 bar. This valve can be supplied by Lambda Physik if requested.

4.3. Assembly on the Laser

The arrangement of the Raman cell on the excimer or dye laser is shown by Fig. 7. The dimensions of the cell may also be obtained from it.

The Raman cell can be mounted by one person. The attachment takes place with two holding angle bars; a detailed cross section through these angle bars and their assembly on the laser may be found in Fig. 8.

The front one is connected firmly with the Raman cell, the rear one is unscrewed (S_2) from the Raman cell and attached to the rear plate of the laser. To this end the holding angle bar with a slit (unscrew the screws S_1) is shifted to the vertical edge of the rear plate; it must then sit on the lower edge. It is attached with screws S_1. Now the entire Raman cell is taken and the slit of the front angle bar is placed at the edge of the laser front plate in the same way (here too, loosen screws S_1). The end of the Raman cell can now be placed on the stage of the rear angle bar and the angle bar and the Raman cell can be joined by screws S_2.

4.4. Connections

Now join a hydrogen gas cylinder with a high pressure regulation valve (at least 40 bar) and the Raman cell. Then use the supplied 6-mm copper line. In no case should you use a plastic hose! The gas filling connection is located at the bottom of the Raman cell, on the right-hand side of the three-way valve. Attach the 6-mm plastic hose on the left-hand connection, which must lead into the open air or into a discharge system. The connections have different threads, so that it is impossible to confuse the hoses.

Now turn the three-way valve to the "closed" position (tip upward) and regulate the pressure on the gas cylinder to 40 bar. Check with a leak tester (Snoopy) whether the connections are tight. You can identify a leak from the fact that with the main valve of the gas cylinder closed, the pressure on the line decreases. Since the Raman cell is pressure-tested by Lambda Physik, its rechecking with nitrogen is only absolutely necessary after a conversion. To this end, fill the Raman cell to 40 bar with nitrogen in the position "fill." Turn the valve to the position "closed." Check whether the pressure in the Raman cell decreases. In about one hour, no decrease in pressure should be visible on the Raman cell manometer. If a drop in pressure is noticeable, check whether in the conversion you have inserted the necessary O-rings between the intermediate compensation elements and have firmly tightened all screws.

If you have carried out the previous pressure tests with nitrogen, close the hydrogen gas cylinder once again and rinse the pressure tube several times with H_2, by filling the Raman cell alternately in the position "fill" to 20 bars and then emptying in the position "exhaust." This guarantees that no oxygen or nitrogen remains in the cell.

Before taking the next step, make sure that you have the Raman cell version which is suitable for the desired spectral range and pump laser.

* The input optics and mechanical components must be adjusted to the pump laser;

* The outlet optics must be suitable for the desired spectral range.

If you have to carry out one of these alterations, please read Section 5.

4.5. Adjustment

Now connect the pump laser. In the adjustment process, work with a weakened beam.

Remove the four screws of the Raman cell which fix the lid and remove it. Then remove mirror holder SH (see Figs. 10 and 15) in front of the pump laser outlet, by loosening the screw in the center and rotating the entire holder with slight traction, until it can be removed.

Now insert the adjusting device J_1. The cross-hair in the center is for the dye laser beam, the rectangle for the excimer laser beam.

Adjustment of the laser beam to the corresponding marking prevents the loss of pump power by partial blocking of the beam.

If in the horizontal position the beam deviates from the mark, you must shift the entire mirror holder receiving unit for S_1 on the coupling tube. To this end, loosen the two screws AS_1, AS_2 which clamp the receiving unit on the tube. They are located underneath the receiving unit and are shown in Fig. 15.

A possible vertical variation should be compensated with a shift in the height of the entire Raman cell. Place more spacing elements under the holding angle bars and the lower edge of the front and rear plate of the laser.

After you have adjusted the pump beam in this way on the adjusting device, place the adjusting screws JS_1, JS_2 (Fig. 10) of the removed mirror holder in the central position. Insert once again the mirror holder SH_1, but do not yet attach its central screw MS. Now remove the mirror holder SH_2 (see Fig. 15) and put in its place the adjusting device J_2 (Fig. 11). For this purpose use the lower portion of the adjusting device.

Now turn mirror holder SH_1 until the pump beams fall approximately on the corresponding cross-hairs of J_1. Tighten the central screw MS of the mirror holder SH_1. With the adjusting screws of SH_1 now introduce the pump beam exactly on the cross-hairs. Apply the adjusting screws of SH_2 likewise in the central position. Now replace the adjusting device J_2 by the mirror holder SH_2 and adjust the beam to the center of the input window of the HDR with the adjusting buttons of the mirror holder SH_2. For this purpose you can use the upper portion of the adjusting device J_2. Adjust the H_2 pressure in the HDR to normal pressure (0 bar). Thus you obtain only the pump radiation at the outlet of the HDR, with which you now adjust further the Raman cell. Screw the red transport-safety device TS_4 in the prism holder. The Pellin-Broca prism is now in a central position.

In the Raman cell with waveguide first insert lens holder LH for the lens L_1 and adjust the focus dye beam with the adjusting screws on the lens holder to the hole of the quartz capillary. You can control this process through the inspection disk S of the Raman cell.

Remove the transport-safety devices TS_1, TS_2, TS_3. Now you can turn with adjusting screws ES_1 and ES_2 the entire Raman cell around the intersection of the optical axis with the vertical through the center of the inspection window. Adjust the cell with ES_1 and ES_2 in such a way that you obtain an outlet beam behind the 90^o prism. Now insert holder PH of the 90^o prism in such a way (rotation and tilting) that the outlet beam is parallel to the optical axis of the Raman cell. To this end it must pass through the center of the beam outlet opening. Measure the pulse energy (for example with an ED 500 or ED 200) and adjust alternately with mirror holder SH_2 or lens holder LH and the adjusting screws ES_1 and ES_2 to maximum energy.

Remove the transport-safety device TS_4. Now you can insert if necessary the diaphragm and the lens L_3 (L_2 for the FIR and IR variants). Obtain the position of the focus from the table in the Raman cell. Here you can also read the wavelength of the various Raman lines, which now appear with an increase in pressure. Turn the prism drive until the desired line emerges from the Raman cell and optimize the energy of the lines with pressure according to the test sheet.

5. Conversion

5.1. Conversion of the Raman Cells for Different Pump Wavelengths

If the Raman cell is pumped with an excimer laser, care must be taken that the high pressure tube length corresponds to the laser gas used (see Table 2). As a rule the Raman cell is supplied by Lambda Physik in accordance with the pump wavelength requested by you. If you yourself wish to use a different excimer gas, please carry out the following steps:

* Rinse the HDR with nitrogen and place the three-way valve on "exhaust" to make sure that no overpressure prevails in the tube.

* Now remove the entrance lens with holder, by loosening the

six screws. Now screw on successively the required number of intermediate elements.

* Take care that each time an O-ring (32 x 2) is inserted in between. Remember that the mirrors S_1, S_2 must also be exchanged (Table 1).

If you use a dye laser as pump source, you must only adjust the two deflecting mirrors S_1, S_2 to the pump spectral range (Table 3). To this end, loosen the central screw of the mirror holder (Fig. 10) and remove it. Loosen the four plastic screws, tighten the mirror carrier on the mirror holder and move the carrier until the center of the desired partial mirror coincides with the marking on the mirror holder.

5.2. Conversion from an Excimer Pumped Variant to a Dye Pumped Variant

Remove the mirror holder receiving unit, by loosening from below the two screws AS_1 and AS_2 (Fig. 15) and take out the receiving unit from tube R. Remove the six screws which join the tube to the Raman cell case. Proceed in the opposite sequence to that of assembly of the tube of the dye pumped variant.

Replace the front attachment brackets by those for assembly on the dye laser (for this purpose you must remove the top portion of the Raman cell case).

Exchange the dielectric mirrors S_1, S_2 with a triple mirror for operation with a dye laser. To this end, remove the mirror holders, remove the four white plastic screws and insert the dye mirror instead of the excimer mirror.

5.3. Conversion from Type 1 to Type 3

Rinse the HDR with nitrogen and place the three-way valve on "exhaust." Unscrew the rear wall of the Raman cell case (with drive case) and the prism carrier plate. The carrier plate is attached to the HDR with four screws which are accessible after removing the plastic caps KK (Fig. 10) in the side wall of the case. Now unscrew the outlet lens and move the quartz capillary in its aluminum tube with the projecting end of the capillary first into the HDR.

If the aluminum tube ends flush with the HDR, clamp it with the headless screw (Fig. 12) (the beginning of the capillary is now in the center of the inspection window), and attach the outlet window for the FIR range. Take care to insert the O-ring.

Replace the input lens by the quartz window. Insert the lens holder LH with the lens L_1, f = 300 mm. Now screw the carrier plate with a set of FIR prisms on the rear wall.

5.4. Conversion from Type 1 to Type 2

Implement the stages as described in 5.2 (including the disassembly of the outlet lens). Replace the lens with the MgF_2 window. Place the O-Ring (32 x 2) on the adapter and screw it with six screws on the window holder. Now you can screw on the rear wall for VUV operation. Place an O-ring (32 x 2) in the groove of the adapter. Screw the vacuum flange on the adapter through the large opening. The flange ends in an NW-50 connection and has a rinsing or evacuation connection with thread.

5.5. Conversion to Motor Drive

You can carry out the rotation of the Pellin-Broca prism and thus achieve line selection with a stepped motor. Moreover, with the motor drive of the prism it is possible to synchronize the adjustment of the dye laser with the Raman cell. To this end, you need, besides the stepped motor, an electronic control system. This consists of an end stop plate for "up" and "down" and also an external motor control system. You can receive all necessary parts on request from Lambda Physik.

For the conversion remove the lid of the drive case on the rear wall of the Raman cell and attach the plate and motor according to Fig. 13. Pull out the band cable through the slit in the lid.

5.6. Exchange or Cleaning of the Lens or a Window

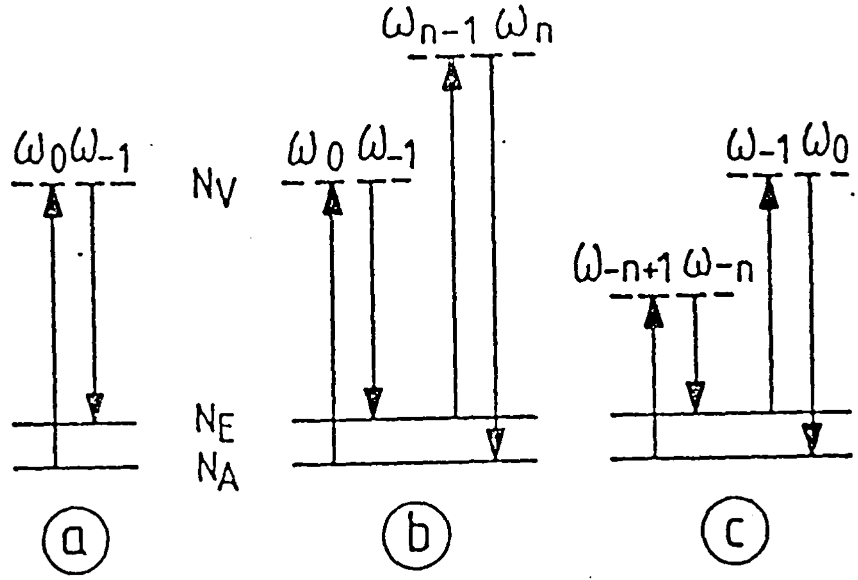
Rinse the Raman cell with nitrogen and unscrew the lens (the window) from the HDR (take care that there is no overpressure in the tube). Loosen the six screws on the holder and take out the lens (the window). Remove the O-ring and clean the lens (window) if necessary with ethanol and lens paper.

In the incorporation, first insert the lens (window) and then move the O-ring over it. Screw the holder on again (Fig. 14).

TABLE 4

Components in addition to HDR	RS75-1500 D	RS75-700 E	RS75-140 D	RS75-140 E	RS75-4500 D	RS75-9000
Steering mirror	RS 76 A	RS 76 B	RS 76 A	RS 76 B	RS 76 A	RS 76 A
Prism	RS 77 A oder RS 77 B	RS 77 B	—	—	RS 77 C	RS 77 D
Input window	RS 78 A	RS 78 A	RS 78 A	RS 78 A	RS 78 B	RS 78 B
Output Window	RS 79 A	RS 79 A	RS 79 B	RS 79 B	RS 79 C	RS 79 C
Input focusing lens	—	—	—	—	RS 80 A	RS 80 A
Output focusing lens	RS 81 A	RS 81 A	RS 81 B	RS 81 B	RS 81 B	RS 81 B
Capillary	—	—	—	—	RS 90	RS 90
Mounting kit including input coupling tube	RS 82 A	RS 82 B/C/D	RS 82 A	RS 82 B/C/D	RS 82 A	RS 82 A

RS 76 A	Two threefold vaporized deflecting mirror for dye laser (320 nm $\leq \lambda \leq$ 970 nm)
RS 76 B	Four pairs of deflecting mirrors for excimer laser (193 nm, 248 nm, 308 nm, 351 nm)
RS 77 A	A small Pelin-Broca quartz prism A small 90° deflecting quartz prism (only for dye lasers)
RS 77 B	A large Pelin-Broca quartz prism A large 90° deflecting quartz prism (for dye and for excimer lasers)
RS 77 C	A small IR glass Pelin-Broca prism A small 90° IR glass deflecting prism (for dye laser and Raman radiation up to 4.5 μm)
RS 77 D	A small CaF_2 Pelin-Broca prism A small CaF_2 90° deflecting prism (for dye lasers and Raman radiation up to 9 μm)
RS 78 A	Quartz input lens for HDR
RS 78 B	Plane parallel quartz input window for HDR
RS 79 A	Quartz outlet lens for HDR
RS 79 B	Plane parallel MgF_2 outlet window for HDR
RS 79 C	Plane parallel CaF_2 outlet window for HDR
RS 80 A	External quartz inlet lens
RS 81 A	External quartz outlet lens
RS 81 B	External CaF_2 outlet lens
RS 82 A	Mechanical components for adjustment to dye laser
RS 82 B/C/D	Mechanical components for adjustment to excimer laser of the 100/150/200 series
RS 90	Quartz capillary as optical waveguide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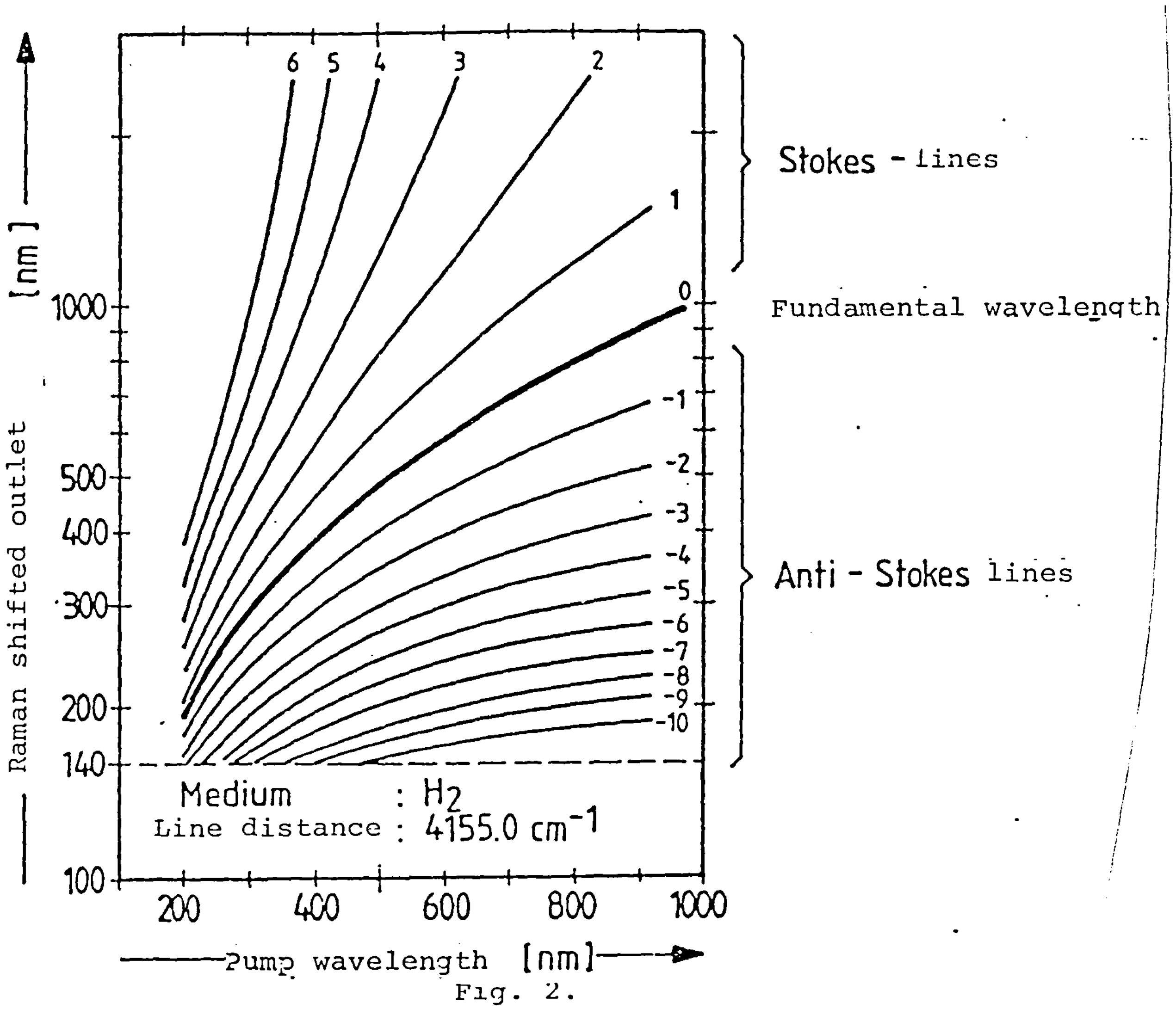
a
b
c

Fig. 1.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Fundamental wavelength
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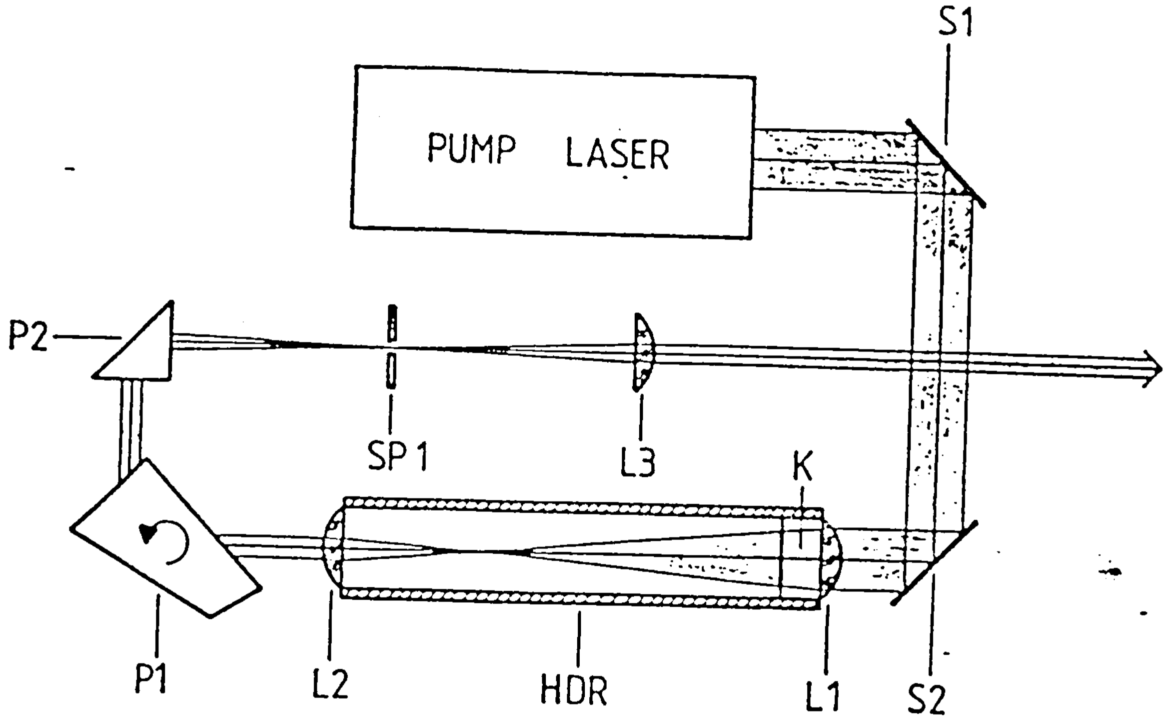
Pump wavelength [nm]

Fig. 2.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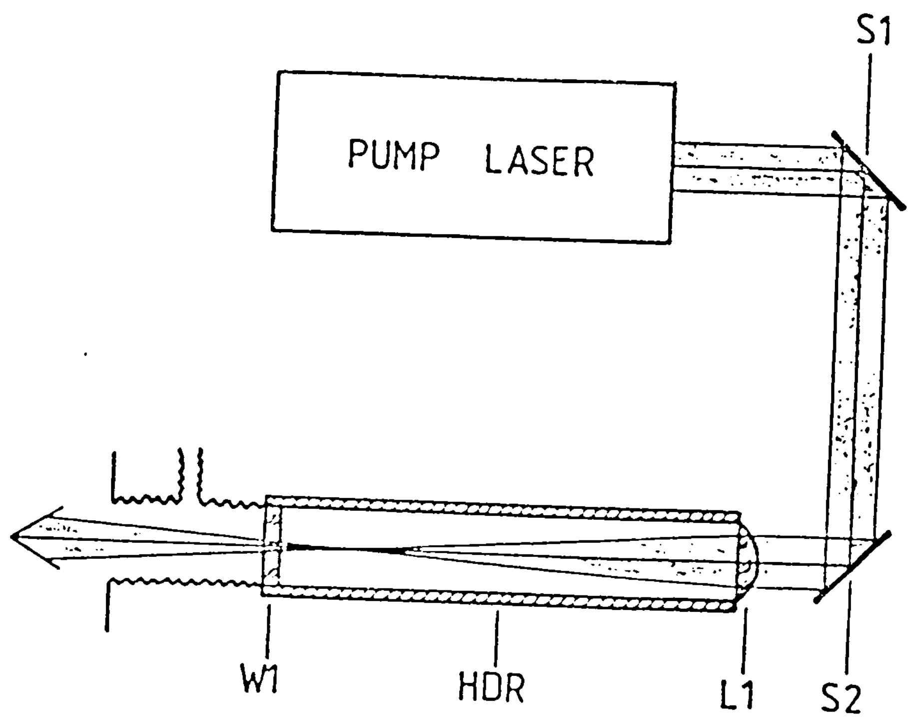
P2
SP 1
L3
K
P1
L2
HDR
L1
S2
Fig. 3.


S1
PUMP LASER
W1
HDR
L1
S2
Fig. 4.

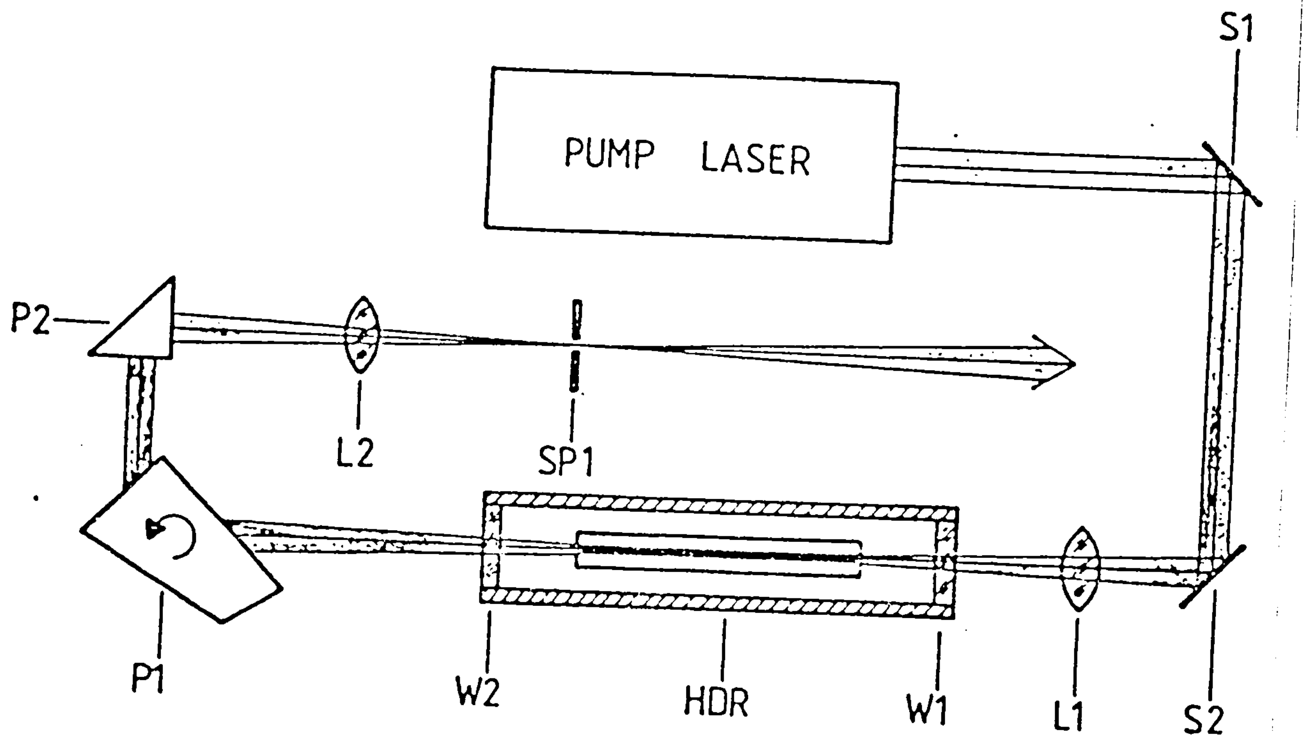

S1
PUMP LASER
P2
L2
SP1
P1
W2
HDR
W1
L1
S2

Fig. 5.

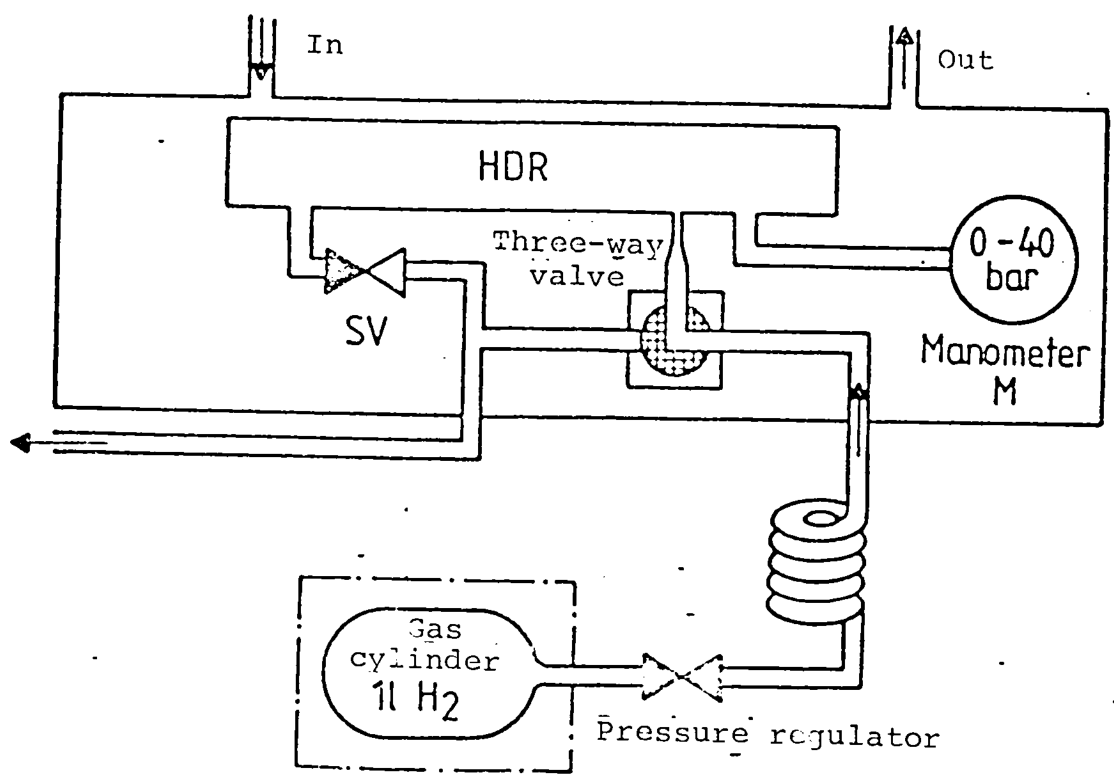

In
Out
HDR
Three-way valve
SV
0 -40 bar
Manometer M
Gas cylinder
1l H_2
Pressure regulator

Fig. 6.

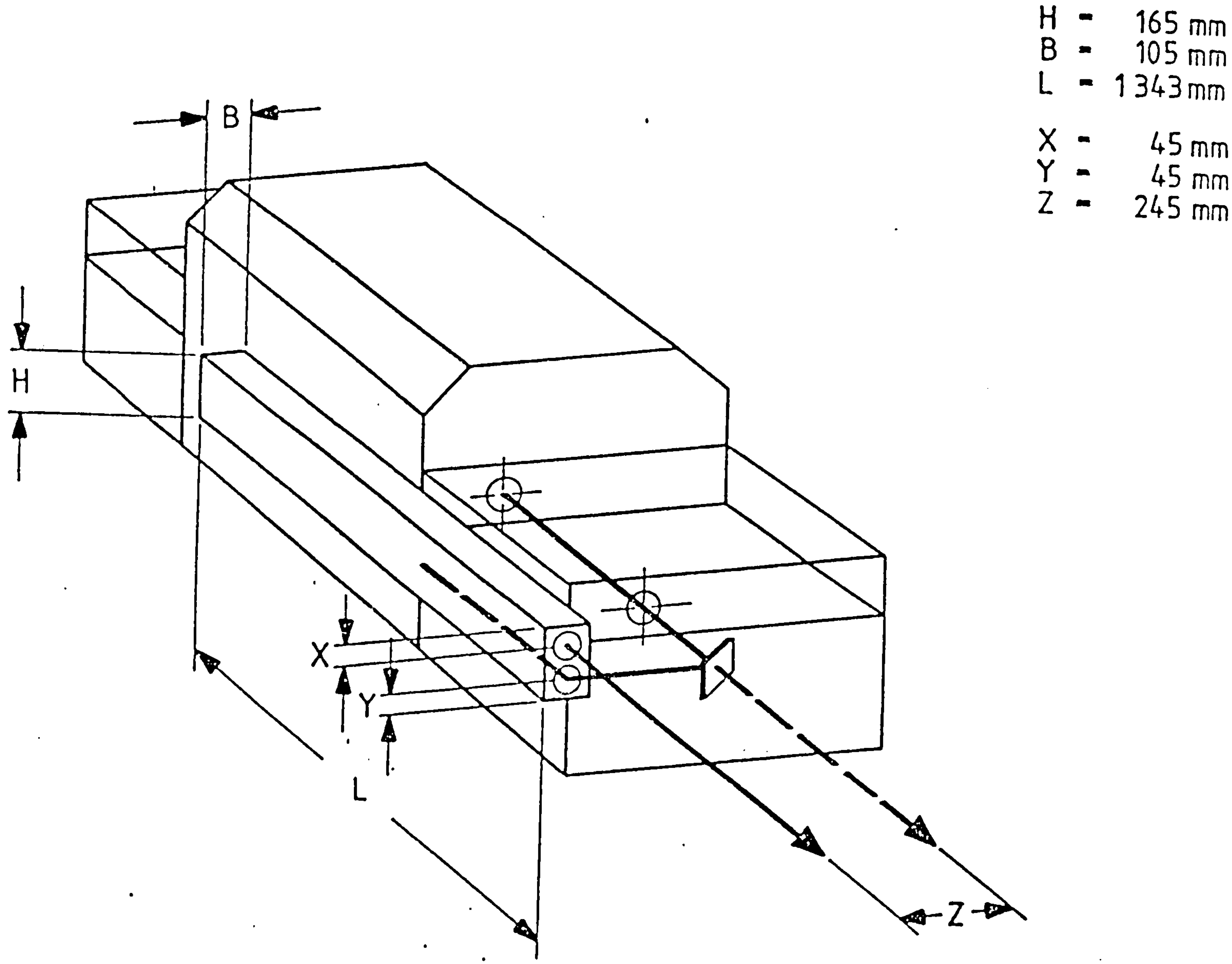


Fig. 7.

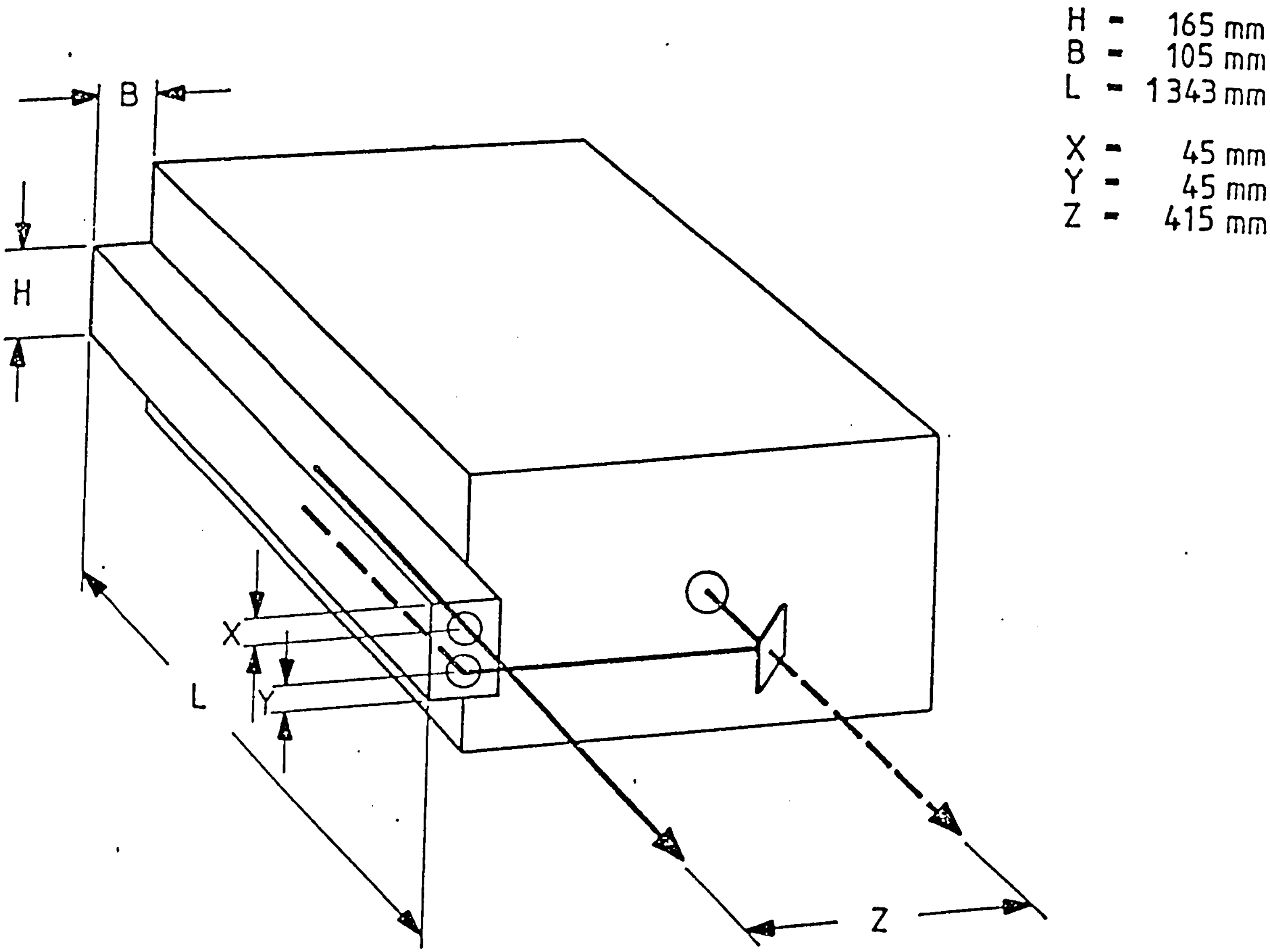


Fig. 7 (cont'd).

H - 165 mm
B - 105 mm
L - 1 343 mm

X - 45 mm
Y - 45 mm
Z - 258 mm

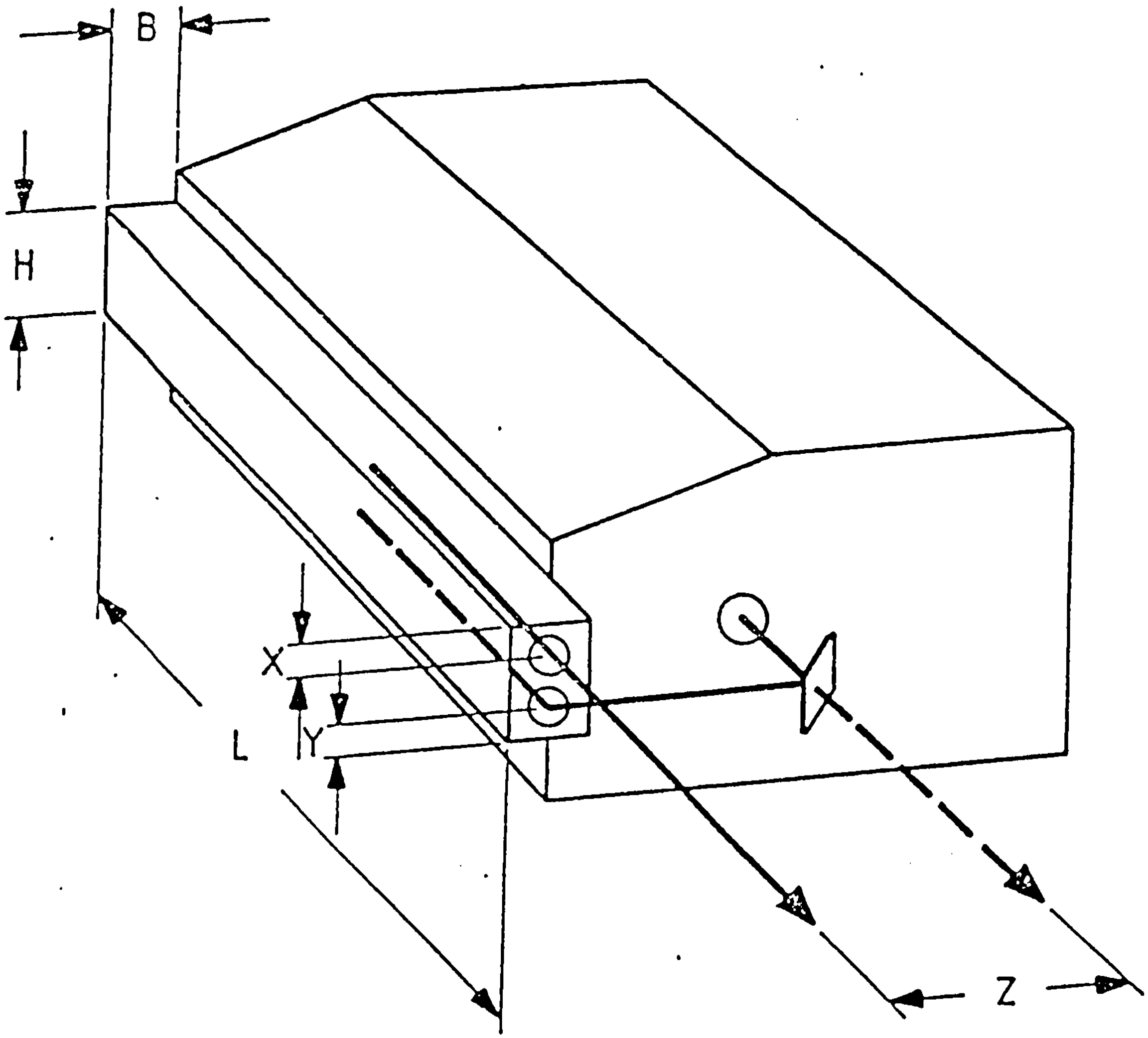


Fig. 7 (cont'd).

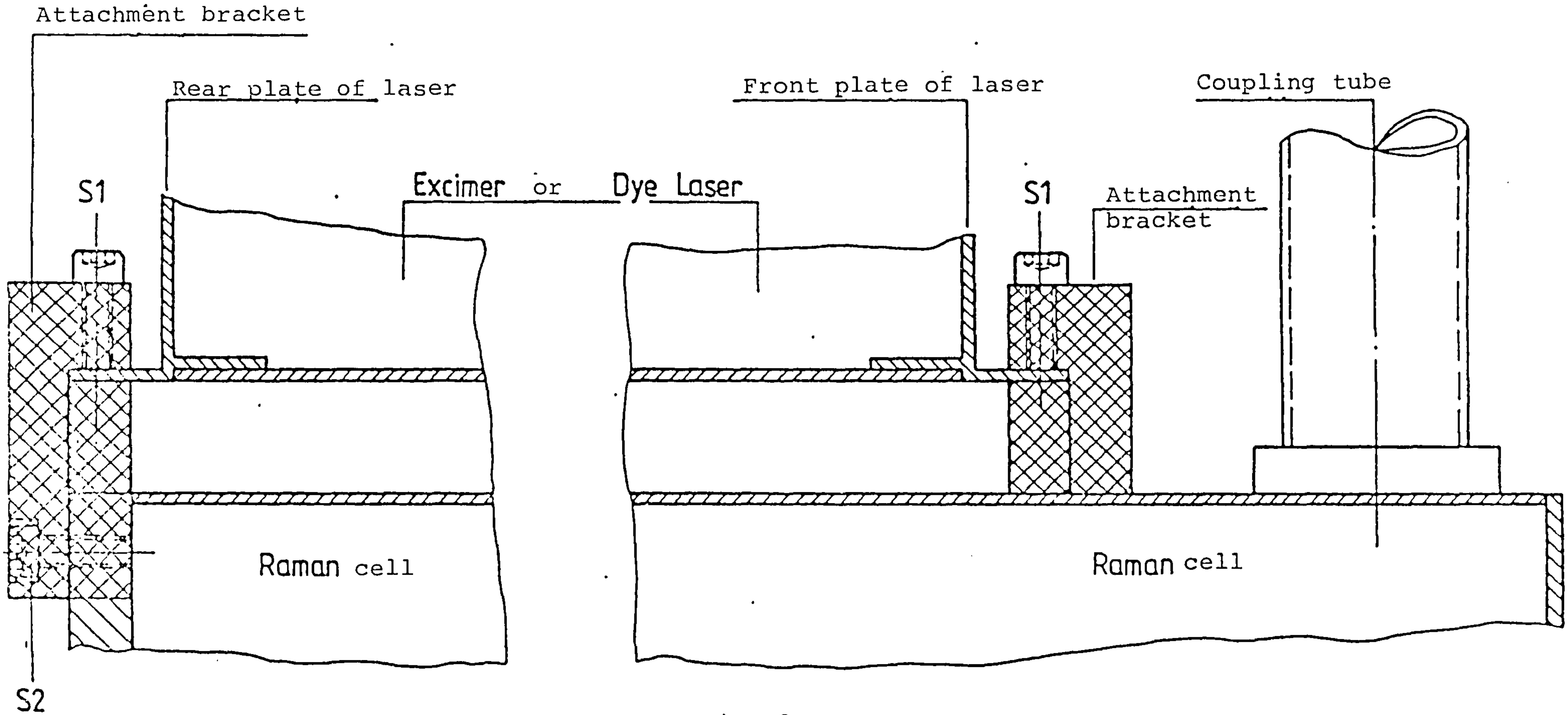

Attachment bracket
Rear plate of laser
Front plate of laser
Coupling tube
S1
Excimer or Dye Laser
S1
Attachment bracket
Raman cell
Raman cell
S2

Fig. 8.

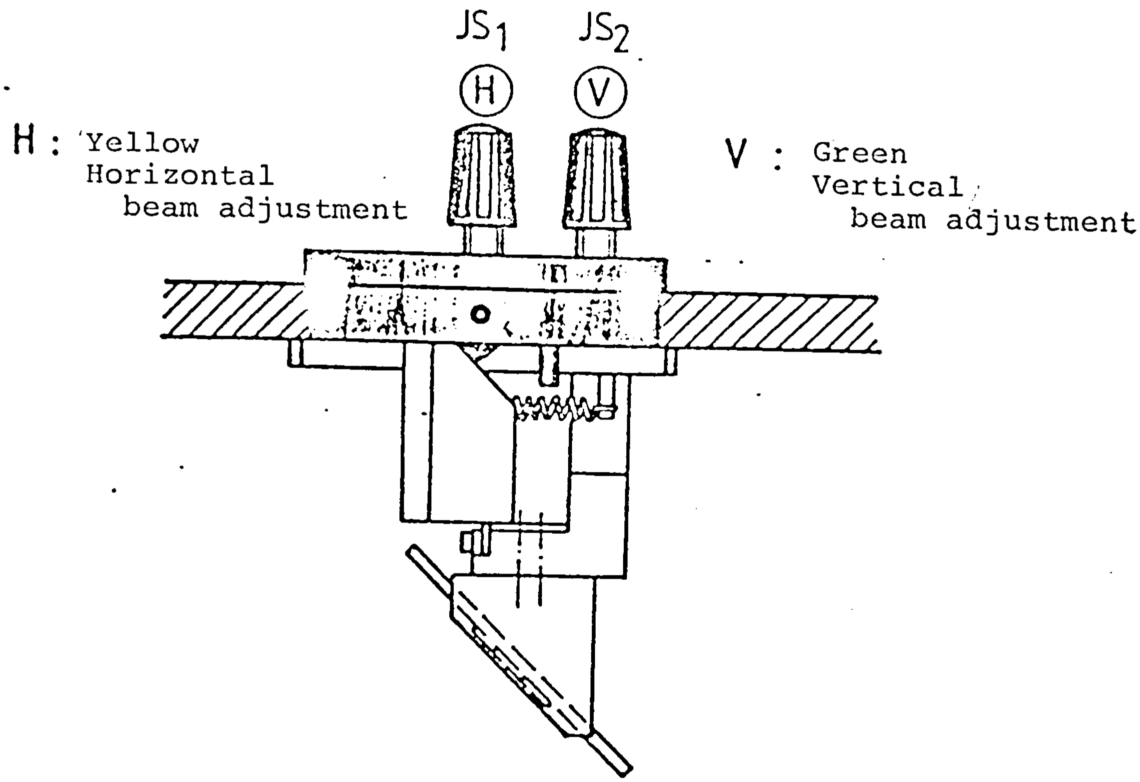

JS1
JS2
H
V
H : Yellow
Horizontal
beam adjustment
V : Green
Vertical
beam adjustment

Fig. 9.

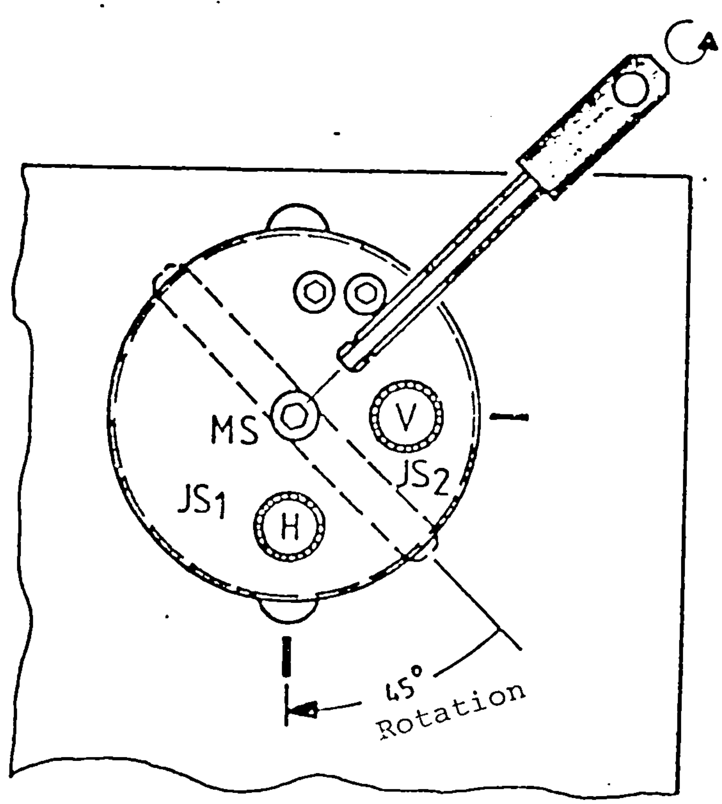

A
MS
V
JS2
JS1
H
45°
Rotation

Fig. 10.

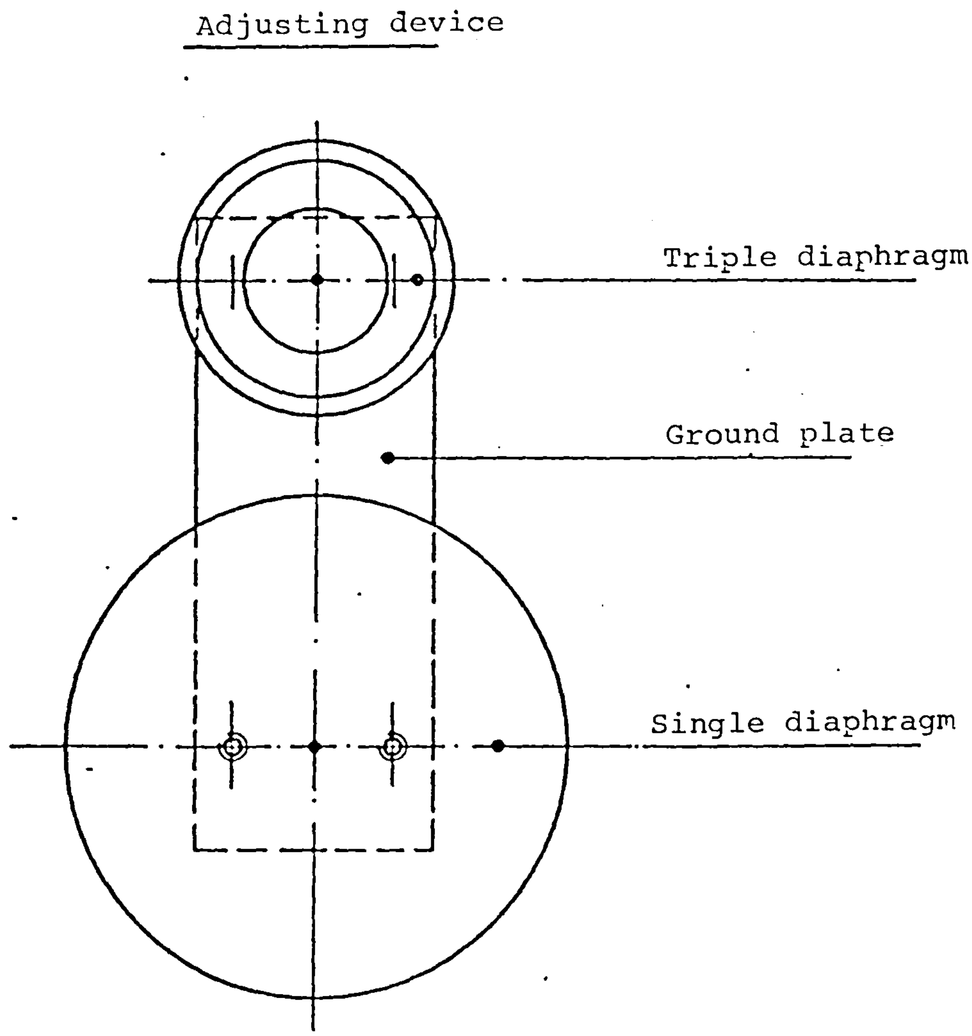

Adjusting device
Triple diaphragm
Ground plate
Single diaphragm

Fig. 11.

Adjusting device

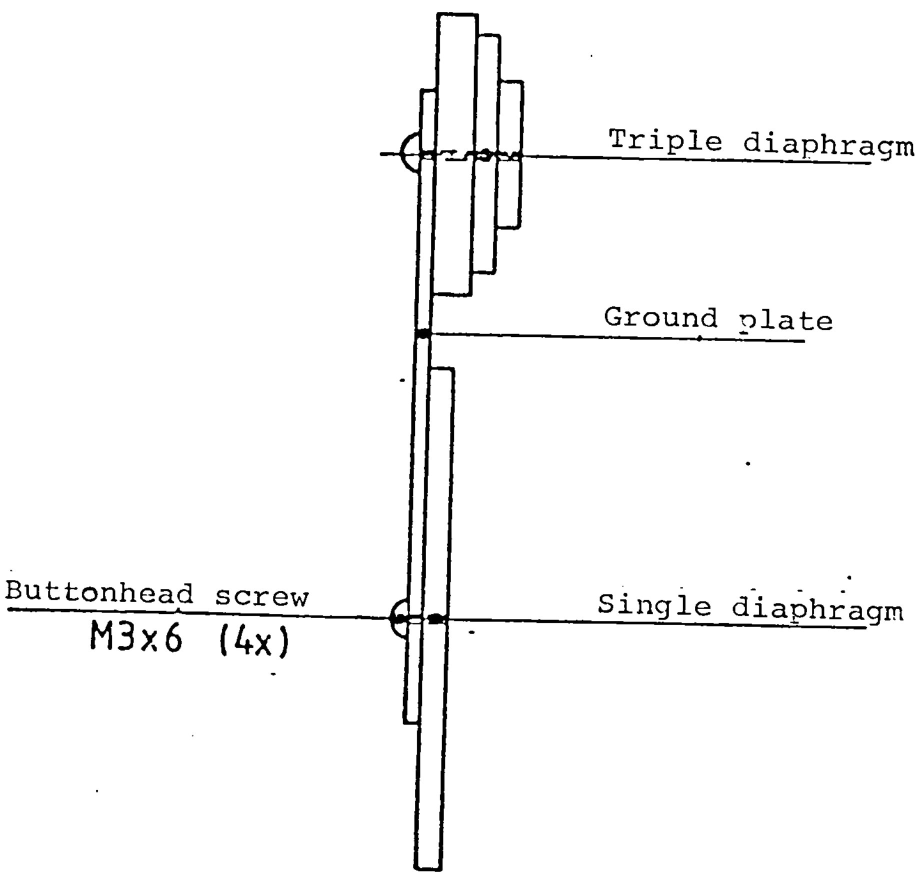


Fig. 11 (cont'd).

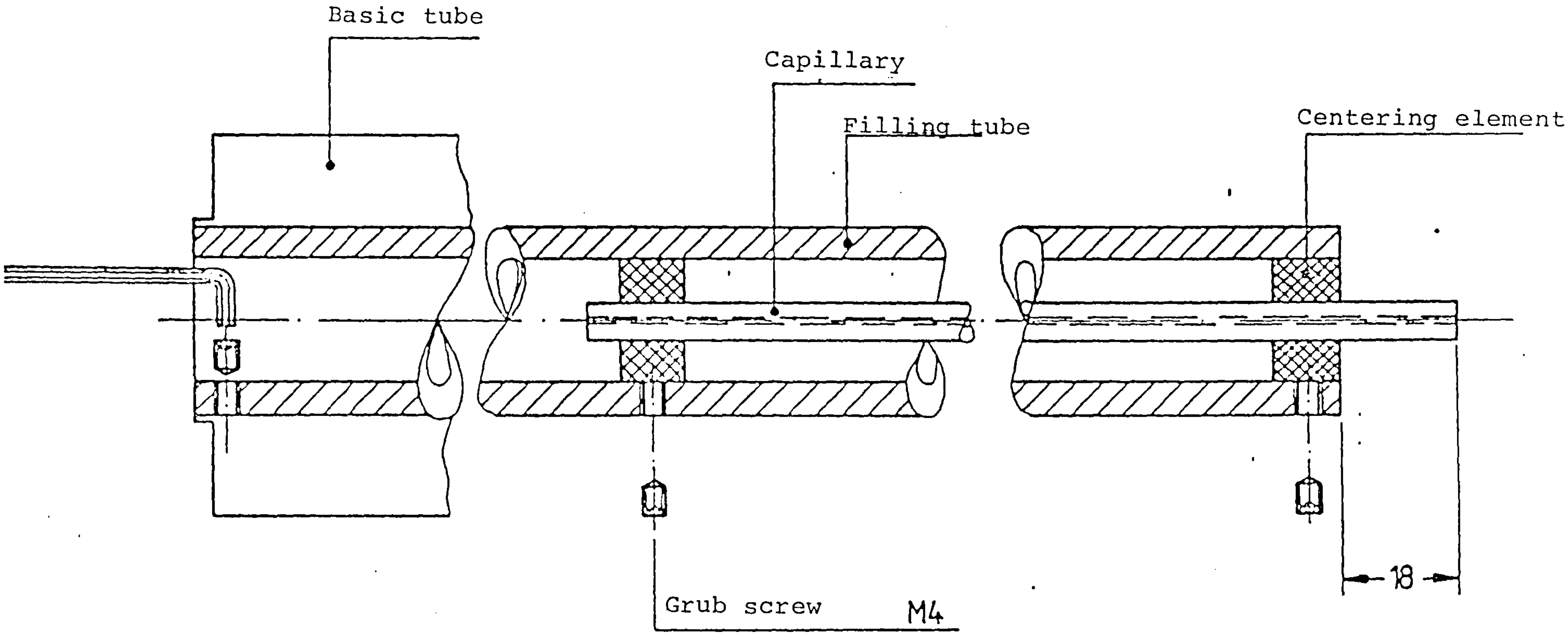

Basic tube
Capillary
Filling tube
Centering element
18
Grub screw M4

Fig. 12.

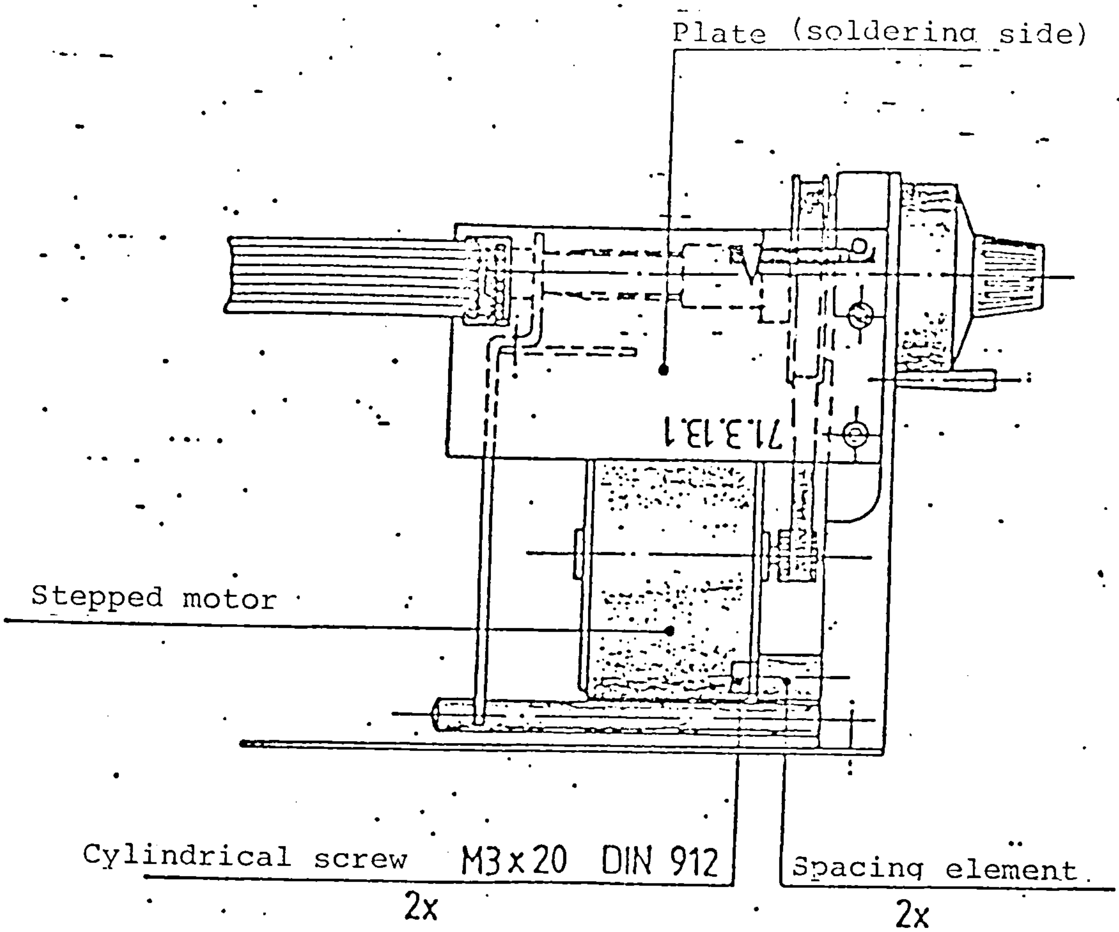


Plate (soldering side)
71.3.13.1
Stepped motor
Cylindrical screw M3x20 DIN 912
2x
Spacing element
2x

Fig. 13.

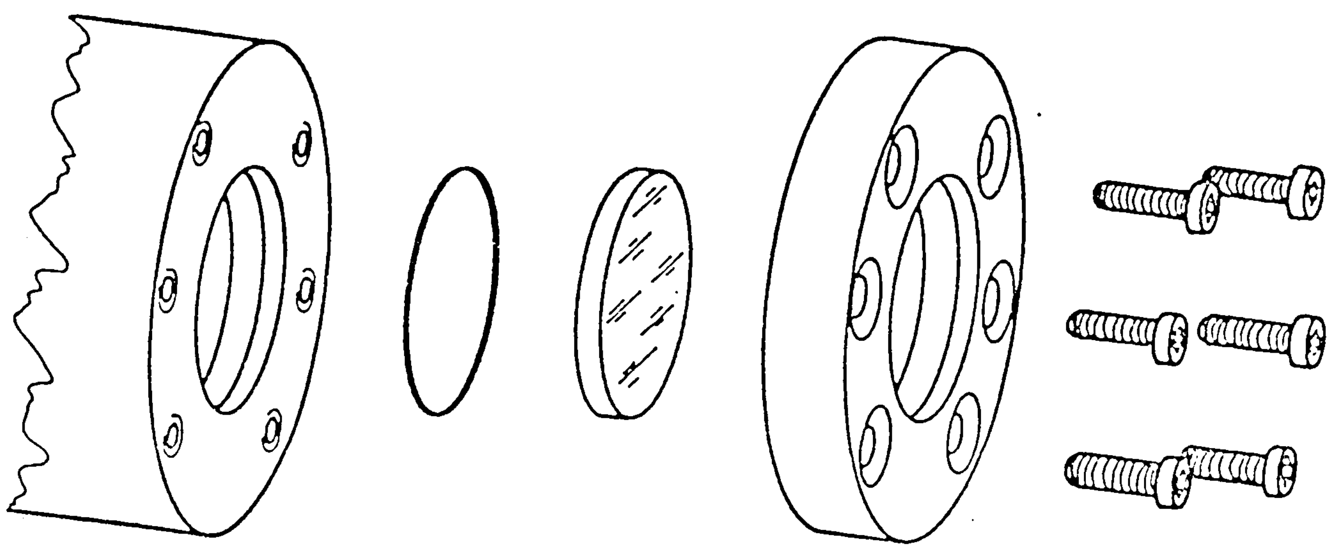


Fig. 14.

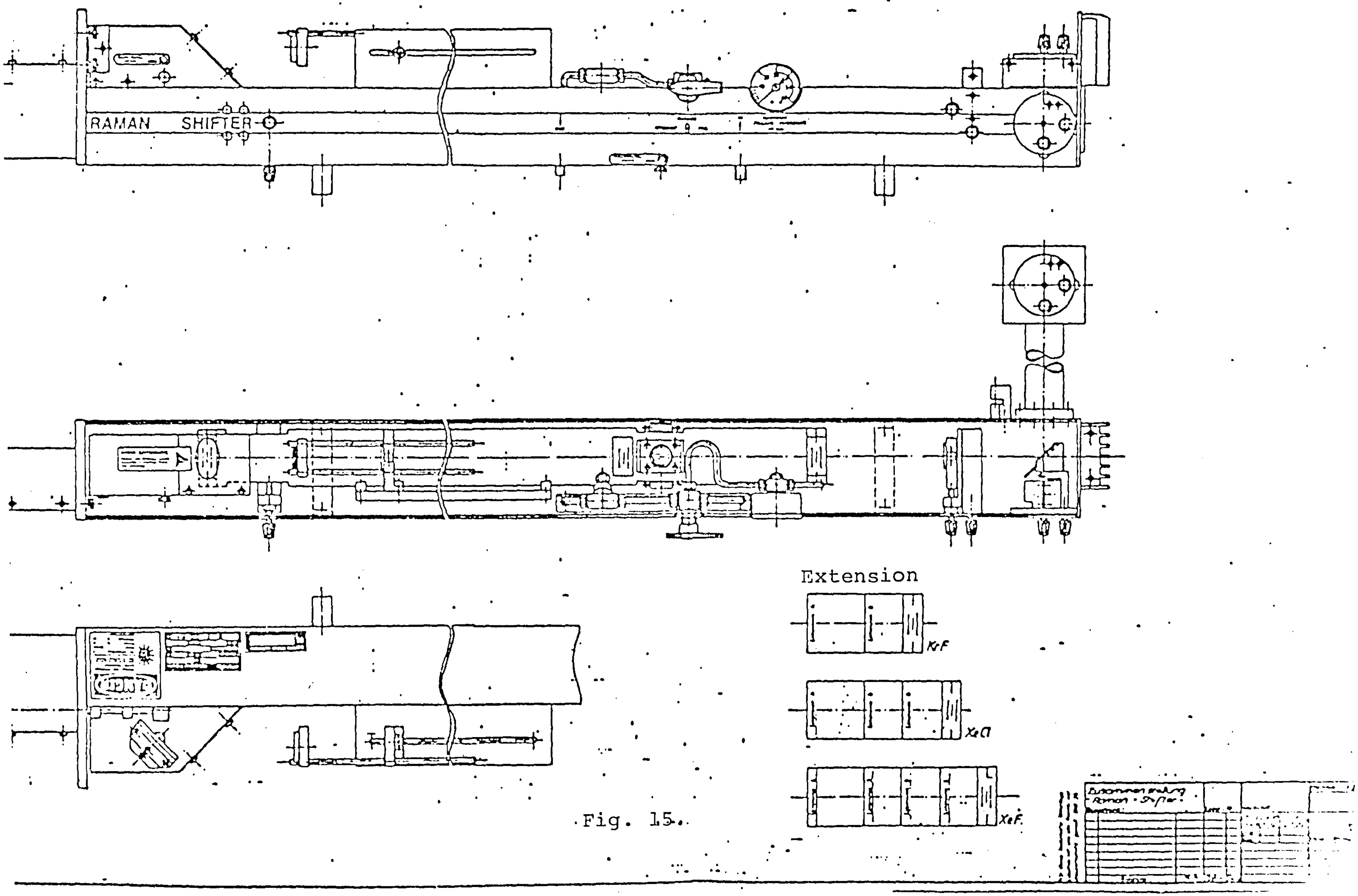


Fig. 15.