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(71) Applicant: **THORN EMI plc**
4 Tenterden Street
London W1A 2AY (GB)

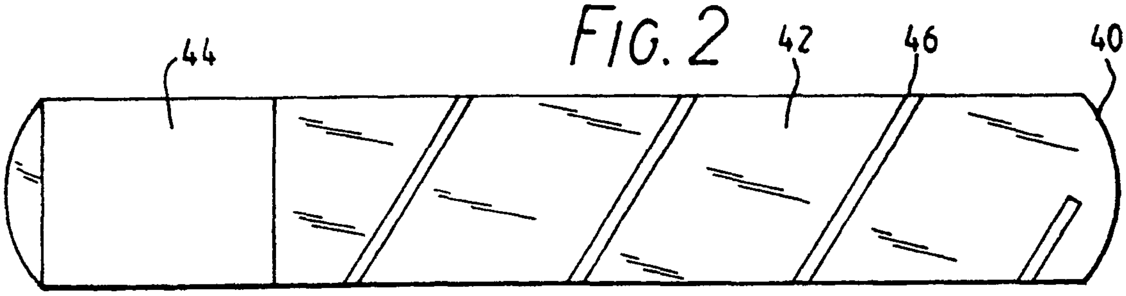
(72) Inventor: **Linden-Smith, Neil Anthony**
101, Highbury Road
Leicester (GB)

(74) Representative: **Sanders, Peter Colin Christopher et al**
BROOKES & MARTIN High Holborn House
52/54 High Holborn
London WC1V 6SE (GB)

(54) A discharge tube arrangement.

(57) A discharge tube arrangement comprising a disharge tube containing a fill and a launcher suitable, when energised with radio frequency (r.f.) power, for exciting surface waves in the discharge tube. A part of the external surface of the discharge tube is coated with an electrically conductive material to form the inner tube of the launcher.

FIG. 2



EP 0 438 253 A2

A DISCHARGE TUBE ARRANGEMENT

This invention relates to a discharge tube arrangement and in particular, though not exclusively, to such an arrangement for use as a light source.

It is known, eg as disclosed in EPO 225753A (University of California), to generate and sustain a low pressure discharge in a gas by using electromagnetic surface waves. Surface waves are created by an energizer (also known as a launcher) which is positioned around and external of, but not extending the whole length of, a discharge tube containing the gas. In such an arrangement it is not necessary to provide electrodes inside the discharge tube. The power to generate the electromagnetic wave is provided by a radio frequency (r.f.) power generator. EP 0225753A further discloses a grounded transparent r.f. shield which can be coated directly onto the wall of the discharge tube to surround the discharge tube.

Our copending European Patent Application No. 89308875.7 discloses a discharge tube arrangement comprising a discharge tube containing a fill and a launcher suitable, when energised with r.f. power, for exciting surface waves in the discharge tube. The launcher is formed as a coaxial structure with an inner and an outer tube. In one method of manufacturing the launcher, a tubular body of dielectric material is formed. This body is then coated, eg by electroplating, sputtering, evaporation or electrolytic deposition, with layers of an electrically conductive material as required to form the coaxial structure of the launcher.

A first aspect of the present invention provides a method of manufacturing a discharge tube arrangement including the steps of :

producing a discharge tube containing a fill ;

and applying a coating of electrically conductive material around and onto a part of the external surface of the discharge tube to form the inner tube of a launcher suitable, when energised with radio-frequency (r.f.) power, for exciting surface waves in the discharge tube.

In contrast to the prior art, the inventor has appreciated that the discharge tube arrangement can be considered as a single structure instead of as a combination of separate entities such as the launcher and the discharge tube. The appreciation of this point makes possible the method of the present invention which has a number of advantages.

In particular, the inventor believes that the efficiency of the discharge tube arrangement may be improved by having the inner tube of the launcher as close as possible to this discharge tube. The method of the present invention provides such a discharge tube arrangement without the need for manufacture of the inner surface of the inner tube and the external surface of the discharge tube to fine tolerances.

Accordingly, a second aspect of the present invention provides a discharge tube arrangement comprising a discharge tube containing a fill and a launcher surtable, when energised with radio frequency (r.f.) power, for exciting surface waves in the discharge tube, the launcher including an inner tube and an outer tube coaxial with said inner tube ;

wherein said inner tube comprises a coating of electrically conductive material applied around and onto a part of the external surface of the discharge tube.

Embodiments of the present invention will now be described, by way of example only, and with reference to the accompanying drawings in which :

Figure 1 shows a known discharge tube arrangement ;

Figure 2 shows, in elevation, a coated discharge tube ;

Figure 3 shows a part of a launcher for use with the discharge tube of Figure 2 to form an embodiment of a discharge tube arrangment provided in accordance with the present invention ;

and Figure 4 shows, for reference, the enhancement of total light output produced by a helical structure wound tightly to a discharge tube in a discharge tube arrangement.

As shown in Figure 1, a discharge tube arrangement, as disclosed in eg our copending European Patent Application No.89308876.5, comprises a discharge tube 20 mounted in a launcher 22. The discharge tube 20 is formed of a light-transmissive, dielectric material, such as glass, and contains a fill 24 of a noble gas, such as argon and an ionizable material, such as mercury.

The launcher 22 is made of an electrically conductive material, such as brass, and formed as a coaxial structure comprising an inner tube 26 and an outer tube 28. A first plate 30, at one end of the outer tube, provides a first end wall for the launcher structure. At the other end of the outer tube 28, a second plate 31, integral with the outer tube 28, provides a second end wall. The inner tube 26 is shorter than the outer tube 28 and so positioned within the outer tube 28 as to define a first annular gap 32 and a second annular gap 33. The first plate 30 has an aperture for receiving the discharge tube 20. The outer tube 28, the first plate 30 and the second plate 31 form an unbroken electrically conductive path around, but not in electrical contact with, the inner tube 26 to provide an r.f. screening structure therearound.

Suitable dimensions for the launcher of Figure 1 are as follows :

Launcher length	7-20mm
Launcher diameter (outer tube 28 diameter)	25-35mm but depends on size of discharge tube 20.
Inner tube 26 length	3-18mm
Inner tube 26 diameter	13mm but depends on size of discharge tube 20.
Length of Launching gap (first gap 32)	0.5-3mm
Length of second gap 33	1-10mm

The thickness of the electrically conductive material is of the order of millimetres, or less, depending on the construction method used.

An r.f. power generator 34 (shown schematically) is electrically connected to the launcher 22 via a coaxial cable 35 and an impedance matching network 36 (shown schematically) consisting of capacitors 36a and inductors 36b. The r.f. power generator 34, the impedance matching network 36, the coaxial cable 35 and the launcher 22 constitute an r.f. powered excitation device to energise the gas fill to produce a discharge.

A dielectric material 37 is provided inside the launcher 22 either as a structural element, e.g. to keep the size of the gaps 32, 33 constant and/or to hold the inner tube 26 in position, and/or to help in shaping the electric field in the gaps 32, 33 for ease of starting or other purposes. Suitable dielectric materials which exhibit low loss at r.f. frequencies include glass, quartz and PTFE.

When the r.f. power supply 34 is switched on, an oscillating electric field, having a frequency typically in the range of from 1MHz to 1GHz, is set up inside the launcher 22. At the first and second gaps 32, 33, this electric field is parallel to the longitudinal axis of the discharge tube 20. If sufficient power is applied, the consequent electric field produced in the gas fill 24 is sufficient to ionise the mercury to create a discharge through which an electromagnetic surface wave may be propagated in a similar manner to the arrangement of EP 0225753A. Accordingly, the launcher 22 powered by the r.f. power generator 34 creates and sustains a discharge in the fill - the length and brightness of the discharge depending, inter alia, on the size of the discharge tube 20 and the power applied by the r.f. power generator 34. Such a discharge tube arrangement may therefore be used as a light source.

The first gap 32 and the second gap 33 each extend axially from respective ends of the inner tube 26, respectively to the first plate 30 and to the second plate 31. The discharge tube 20 extends from one end of the launcher 22 and so the first gap 32 is effective as a launching gap to create a discharge. The second gap 33 complements the effect of the first gap 32 and is advantageously larger than the first gap 32.

Figure 1 also shows a helical structure 38, having 3 turns, and formed of an electrically conductive material, such as copper, extending along the discharge tube 20. An earth connection is provided from the structure 38 to the first plate 30 of the launcher 22. The effect of the helical structure 38 is to enhance the light output of the discharge tube arrangement. The helical structure 38 also provides some r.f. screening.

Figure 2 shows an electrodeless discharge tube 40 containing a fill 42. Coated onto the external surface of the discharge tube 40, near one end, is a band 44 of aluminium. A 3-turn helix 46, also coated onto the external surface of the discharge tube 40, extends therealong. A variety of methods, known to those skilled in the art, may be used to apply the coatings of electrically conductive material onto the external surface of the discharge tube 40. In one method, the discharge tube 40 is masked with tape to produce a stencil, leaving exposed the surfaces to be coated. The masked discharge tube is then placed in a vacuum coating chamber and a tungsten filament is used to evaporate aluminium from lengths of aluminium wire onto the discharge tube. In another method, the helix 46 is applied as silver conducting paint.

In the examples used, the discharge tube had a length of 120 mm and a diameter of 13 mm. The axial length of the band was 20 mm and the 3-turn helix had a pitch of 30 mm.

To form a discharge tube arrangement, an outer part of a launcher without the inner tube is constructed. The coated discharge tube is inserted into the launcher outer part and an electrical connection is made to the band 44 for the supply of r.f. power. The electrical connection may include a spring-loaded contact or a wire ring to make contact with the band 44. The band 44 is then effective as the inner tube of a launcher. The outer part of the launcher may be similar to that of Figure 1 or may be as shown in Figure 3.

Figure 3 shows a launcher outer part 50 including a tubular body 52 of dielectric material having an end wall 54. An electrical connection through the dielectric body 52 for suppling r.f. power to an inner tube is shown schematically as a coaxial cable 56. A coating 58 of aluminium has been applied to the external surfaces of the dielectric body 52 to form the outer tube 60 and end walls 62, 64 of a launcher.

In either arrangement, the sizes of the first and second annular gaps of the launcher are determined, inter alia, by the length of the discharge tube, the position of the aluminium band on the discharge tube and the dimensions of the launcher outer part. An earth connection from the coated helix to the outer tube or end walls of the launcher is provided, including a wire ring around the discharge tube make contact with the helix.

Discharge tube arrangements including a coated discharge tube as described with reference to Figure 2 have been tested. The band of aluminium was found to be satisfactorily effective as the inner tube of the launcher. The silver painted helix had no measurable effect on the total light output of the discharge tube arrangement and this was believed to be due to its relatively high resistance (around 200) though it is envisaged that this can be improved. It was found that the aluminium helix, which had a resistance of less than 1 , produced an increase in total light output similar to the increase effected by a copper wire helix wound tight to the discharge tube. For reference, Figure 4 shows the effect of a 5 turn copper helix structure wound tight to the discharge tube wall on the total light output of a discharge tube arrangement operated at 129 MHz. The key to the graphs is given below :

Graph	Structure
66	No structure
68	earthed helix
70	Indicates 50 1m/W

The total light output from a discharge tube arrangement surrounded by an unearthed helix was identical to that without the helix present - the amount of material in a 5 turn helix is insufficient to obscure a measureable proportion of the light output. In this example, there was about a 25% increase in total light output caused by the presence of the earthed helix. Thus any mesh structure obscuring less than 25% of the surface area of the discharge tube would comprise an insufficient quantity of material to obscure the increase in total light output produced by the presence of the structure. For a mesh of wire thickness 0.55mm, this results in a mesh hole size of about 4mm.

Modifications to the embodiments described and within the scope of the present invention will be apparent to those skilled in the art. In particular, it is evident that for a discharge tube arrangement in which the discharge tube is positioned to extend from both ends of the launcher the coating of electrically conductive material for the launcher inner tube and the helical structure will be positioned accordingly. The helical or other light output enhancing structure may be provided separately from the inner launch tube.

It is further envisaged that the dimensions of the first and second annular gaps may be more precisely defined by coating contacts for the end walls of the launcher onto the discharge tube. In this way, the length of each gap is defined by the separation between the edges of each contact and the respective edges of the coated inner tube.

Claims

1. A method of manufacturing a discharge tube arrangement including the steps of :
   producing a discharge tube containing a fill ;
   and applying a coating of electrically conductive material around and onto a part of the external surface of the discharge tube to form the inner tube of a launcher suitable, when energised with radio-frequency (r.f.) power, for exciting surface waves in the discharge tube.

2. A method according to Claim 1 further comprising the step of applying another coating of electrically conductive material to form a structure extending along the external surface of the discharge tube, said structure being separated from said inner tube and comprising an insufficient quantity of material to obscure an increase in total light output over the total light output of a discharge tube not having said structure.

3. A method according to Claims 1 or 2 wherein said electrically conductive material is aluminium.

4. A method according to any one of Claims 1 to 3 wherein the step of applying said coating comprises the steps of masking parts of the external surface of the discharge tube and of applying said electrically conductive material by vacuum coating.

5. A discharge tube arrangement comprising a discharge tube containing a fill and a launcher suitable, when energised with radio frequency (r.f.) power, for exciting surface waves in the discharge tube, the launcher including an inner tube and an outer tube coaxial with said inner tube ;

wherein said inner tube comprises a coating of electrically conductive material applied around and onto a part of the external surface of the discharge tube.

6. A discharge tube arrangement according to Claim 1 further comprising a structure of electrically conductive material coated onto and extending along the external surface of the discharge tube, whereby, in use, the discharge tube produces an increase in total light output over the total light output of a discharge tube not having said structure, wherein said structure comprises an insufficient quantity of material to obscure said increase in total light output and said structure is separated from said inner tube.

7. A discharge tube arrangement according to Claims 5 or 6 wherein said electrically conductive material is aluminium.

8. A discharge tube containing a fill and including a coating of electrically conductive material applied around and onto a part of the external surface of the discharge tube.

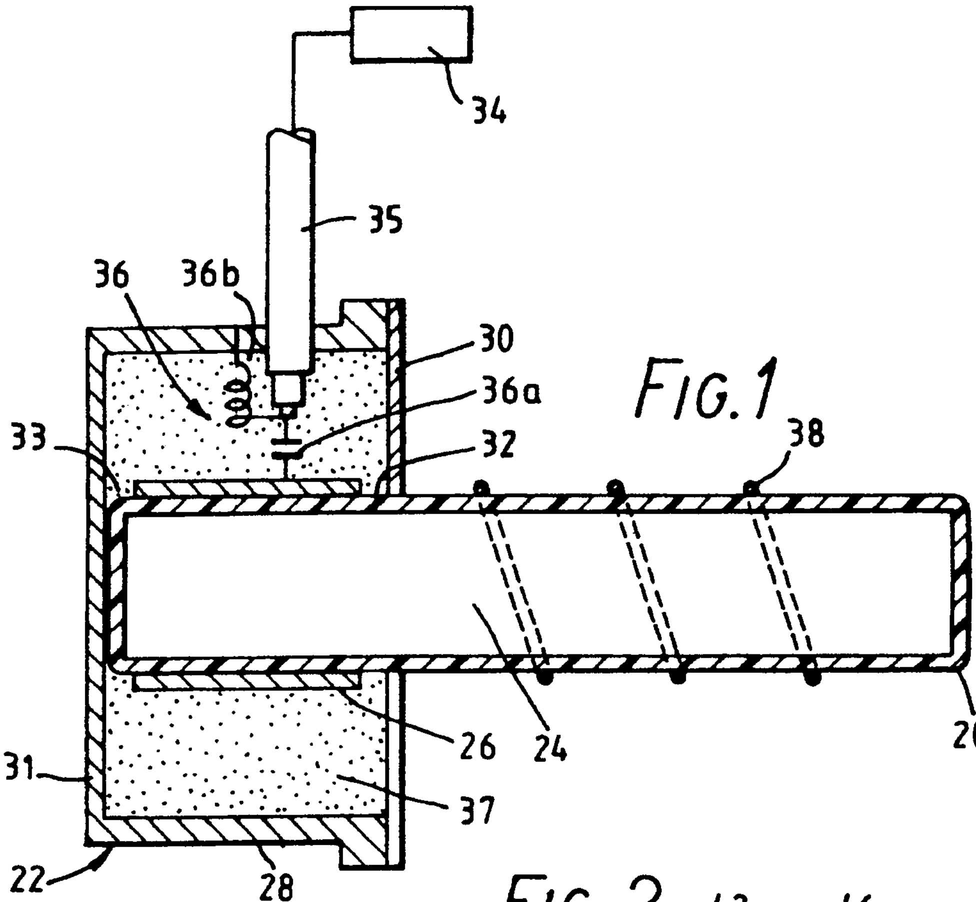


FIG. 1

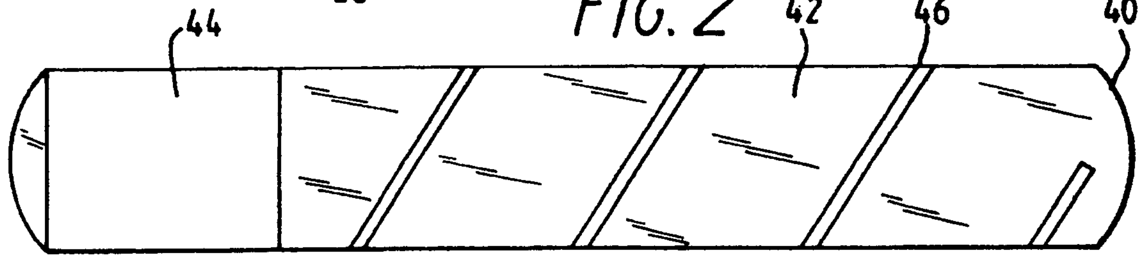


FIG. 2

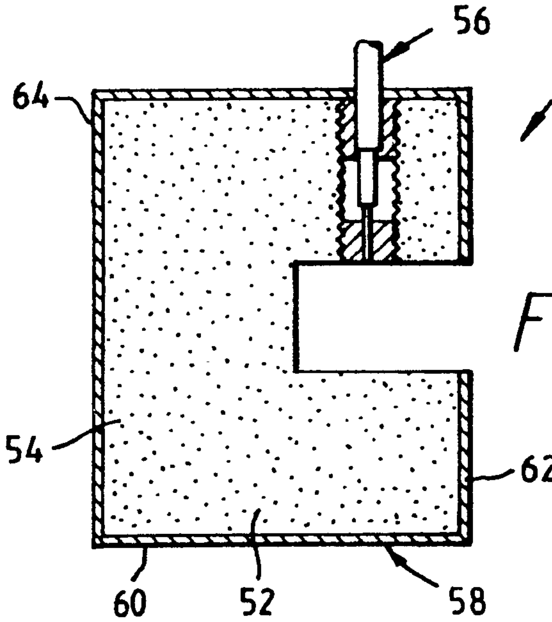
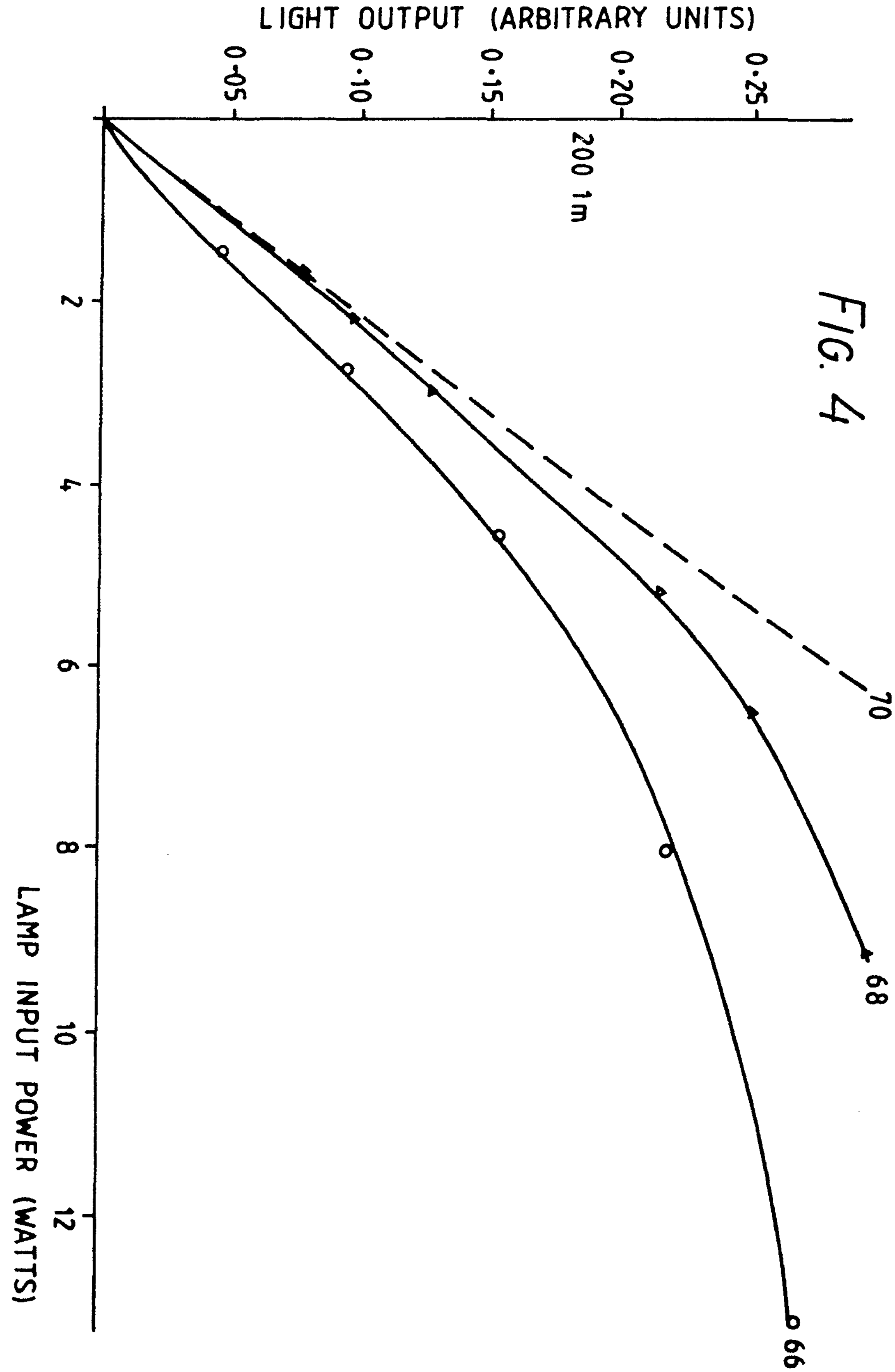


FIG. 3

FIG. 4


LIGHT OUTPUT (ARBITRARY UNITS)
0·05
0·10
0·15
0·20
0·25
200 1m
2
4
6
8
10
12
LAMP INPUT POWER (WATTS)
70
68
66