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NOTES ON EXPERIMENTS

'Notes on experiments' enables teachers at both sixth-form and tertiary level to share their ideas with other readers. *Physics Education* welcomes submissions from readers who know of some simple improvement to a commercially made piece of apparatus, or who have designed a new gadget or improved a standard experiment. In particular the Editor would welcome brief descriptions of experiments devised or procedures evolved during the course of project work or investigation undertaken by students; such submissions should be made under the joint name of the teacher and the student.

THE LENS–PINHOLE SPATIAL FILTER

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In many laboratory applications the output beam from a conventional laser is too narrow. Expanding the beam using a lens or mirror is simple, but often the expanded beam will have unwanted intensity fluctuations. Since the unexpanded beam has a Gaussian intensity profile, the expanded beam should also have a Gaussian intensity profile. However, because of dust on the lens or in the air, or because of imperfections within the lens, the expanded beam is not Gaussian. When it is important to have an expanded beam which has a Gaussian intensity profile, a lens–pinhole spatial filter (LPSF) is used. This note describes the use and construction of a versatile, stable and economical LPSF assembly which can be constructed in most workshops.

A LPSF consists of a converging lens having a short focal length, a metallic foil which has a small (typically a few micrometres diameter) pinhole formed in it and a mechanism which allows the positioning of the light focused by the lens to pass through the pinhole in the foil (Nussbaum and Phillips 1976). By choosing the appropriate combination of lens focal length and pinhole diameter, the light scattered by dust and imperfections will be obstructed, allowing a clean Gaussian beam to diverge from the pinhole. For good beams with maximum power,

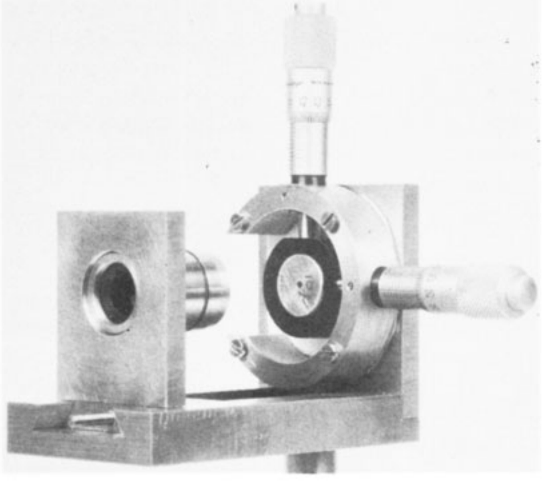
$$D \simeq 2\lambda f/a$$

where D is the pinhole diameter, λ is the wavelength of the light being used, f is the lens focal length and a is the input beam diameter. Microscope objectives are commonly used to focus the laser beam, since they have short effective focal lengths and small apertures.

Our goal was to design and construct a LPSF assembly with good thermal and vibration stability, and at a lower cost than commercially available units (Ealing-Beck catalogue no. 22-5854 £122 in September 1977, without pinhole and objective; Nuclear Research Corporation catalogue no. 900 \$385 in December 1977, with 10× objective and 25 μm pinhole). We wanted the device to be capable of precise and easy alignment, yet rugged enough for normal student use. We chose to purchase the pinholes, microscope objectives and micrometer heads. For a 10× objective, a 25 μm pinhole and two micrometer heads, our cost was about £60. The supplies we needed for the remainder of the LPSF (brass stock, brass screws, springs, sheet steel, Teflon sheets and Alcomax 2 rods—Alcomax 2 standard M 8746 rods capable of machining and magnetising along the axis can be obtained from Darwins Magnets International, Tirsley, Sheffield) were available in our workshop. Figure 1 is a photograph of a fully assembled LPSF. Figure 2 is a photograph of the sub-assembly units, showing the microscope objective carrier, the pinhole mount and carrier, and the main frame to which these are attached.

We chose to purchase our pinholes formed in platinum discs, 3 mm in diameter. We then recessed a hole in a 15 mm diameter brass disc and mounted the pinholes in this disc. Pinholes can be purchased premounted in 15 mm plastic discs. The brass disc is then mounted in a recessed hole in a piece of Alcomax 2. The Alcomax 2 is machined flat on two sides which are perpendicular to each other and to the flat end of the disc. Prior to inserting the pinhole mounts, the Alcomax 2 is placed in a strong (> 2 T) magnetic field

Figure 1 Fully assembled lens-pinhole spatial filter. Light is incident from the left on to the back of the microscope objective. When in use the microscope objective is typically a few millimetres from the pinhole, which is recessed below the hole in the brass disc



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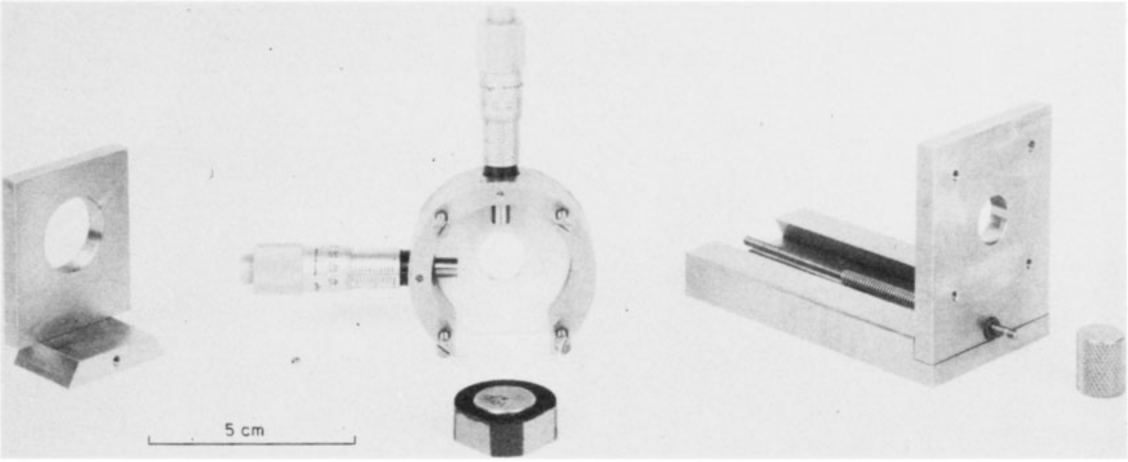

Figure 2 Subassembly components of the lens-pinhole spatial filter. The slide carrier for the microscope objective is on the left. The head assembly for moving the pinhole is shown at the centre. The base and screw assembly are shown at the right. The pinhole is in a platinum disc, 3 mm in diameter, mounted in a brass holder, 15 mm in diameter, which is, in turn, mounted in an Alcomax magnetised holder. The micrometer heads are not magnetised

along its axis for about 1 h. When fully magnetised, the Alcomax 2 should attach itself firmly to the two micrometer heads, yet slide smoothly on the Teflon coated sheet steel. There should be no backlash when reversing micrometer direction, and the Alcomax 2 should slide smoothly on the other micrometer.

To use the LPSF in an optical system, first align the system with the unexpanded laser beam. Remove the pinhole mount from the LPSF and insert the LPSF into the optical path so that the unexpanded laser beam is incident on the 'back end' of the microscope objective. Adjust the LPSF so that the reflections from the microscope objective all coincide and surround the incident laser beam. A white card with a small hole in it (to pass the laser beam) is useful for this alignment. Centering the back-reflections on to the hole can be done quite easily. Insert the pinhole mount into the micrometer heads, with the microscope objective a few millimetres from the pinhole. Move the pinhole mount using the micrometers until a small spot can be seen on a white card (no hole this time) placed a few centimetres in front of the pinhole. Screw the microscope objective toward the pinhole, enlarging the spot on the card. Carefully adjust the micrometers if the spot becomes weaker or off-centre. Alternate adjustments of the microscope objective and pinhole mount until a bright, diverging beam is obtained, with few or no diffraction rings surrounding it. The best focus has been obtained when an intentional moving of the pinhole mount causes an abrupt obliterating of the output beam. If these procedures have been carefully followed, the centre of the output beam should still be on the original optical axis, as defined by the unexpanded beam.

Acknowledgments
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Reference

Nussbaum A and Phillips R A 1976 *Contemporary Optics for Scientists and Engineers* (London: Prentice-Hall) p272. Shows good photographs of an unfiltered and a filtered beam

MODIFICATION OF A UNILAB V.L.F. OSCILLATOR

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The Unilab v.l.f. oscillator (062-632) provides an approximately sine wave output at 0.1 Hz and 0.2 Hz. This note describes how it can be modified to give an infinitely variable frequency between 0.1 Hz and 10 Hz. It is then possible to investigate resonance in *LCR* circuits using only meters and a stopwatch. The cost of the components is about £6 and the modification takes about six hours, including circuit assembly and adhesive curing time. The existing power supply is retained and no machining of the

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