COHSI: a lens array and fibre feed for the near infra-red

Matthew A. Kenworthy, Ian R. Parry, Kimberly A. Ennico

Institute of Astronomy, University of Cambridge, Madingley Road, Cambridge CB3 0HA, United Kingdom

Abstract. Two fibre optic feeds were designed and constructed for the Cambridge OH Suppression Instrument (COHSI). We discuss the techniques used in their manufacture.

1. Introduction

COHSI is designed to suppress the OH airglow in the near infra-red 1–1.8 μm allowing observations of faint high-redshift galaxies, gravitational arcs and other faint extended objects (Piché et al. 1997). Its modular design allows easy transport between telescopes (Figure 1) it is comprised of an integral field unit (IFU), an OH suppression unit and a cryogenic spectrograph—the last two sit on the floor of the observatory.

Two fibre feeds are used. 110 μm fibres run from the 100-element IFU on the Cassegrain focus and are reformatted into a curved fibre slit in the OH suppressor. A second set of fibres with a core diameter of 200 μm run from the suppressor into the cryogenic spectrograph. The two fibre feeds are physically joined together at the curved double slit so the whole assembly is a single unit (Figure 5).

2. Protecting the fibres

Although fibres are strong in tension, they are easily broken with finger-pressure against a sharp corner or when bent into a small radius. With the fibres we use, this radius is about 2 cm.

We use plastic-sheathed steel-wound conduit to protect the fibres from one end to another—they are flexible but can withstand the full weight of someone standing on them whilst their coil-wound construction makes them flexible. They also have a minimum bend radius of 15 cm, making them well suited for use with optic fibres. Because of their ability to bend and change length we put a box into the fibre path. This ‘strain relief’ box contains a coiled loop of fibre optic that can expand or contract according to the extension of the conduit, thereby preventing tension being inadvertently put onto the fibres.

3. The Integral Field Unit (IFU)

The IFU is comprised of 100 hexagonal achromatic doublets cemented onto an optical flat substrate. Individual lenslets were glued onto the flat with an optical glue that cures upon exposure to UV light (Figure 2).

This substrate is placed into mechanical contact with two other optically flat pieces of glass, the three together forming an achromatic flat whose thickness is equal to the focal length of the doublets.

Concentric steel ferrules are glued over the outer polyamide layer of the $110\,\mu$m core optic fibre, providing a greater surface area for gluing of the fibre and aiding the polishing of the fibres. After rough grinding with silicon oxide powder, the fibres are polished with $12\,\mu$m aluminium oxide, then with $6\,\mu$m, $3\,\mu$m and $1\,\mu$m oil/diamond suspension on silk cloths.

In order to position the fibres the field lens for the fore-optics is placed in front of the lens array. A back-illuminated fibre placed correctly on the back of the array will form an image of the fibre on a graticule in the focal plane of the field lens. This image is viewed with a microscope eyepiece connected to a CCD camera. When the fibre image is centred in the graticule, optical glue then fixes the fibre in place.

To ensure further mechanical strength the fibre ferrules are encased in re-enterable polyurethane which supports them but does not apply any lateral force that could move the fibres out of position.

4. The OH Suppressor double fibre slit

Flexible steel conduit holds the 100 fibres and feeds them into the centre of the suppressor, whose design is based on a Schmidt camera with an 86 cm diameter primary mirror (Figure 3). In this design, the ends of the input and the output fibres sit between the primary mirror and the corrector plate on the curved focal surface of the Schmidt. Due to chromatic field aberrations the $200\,\mu$m output fibres have to be within $500\,\mu$m of the $110\,\mu$m input fibres, sitting on the optical axis of the camera.

In order to get the two sets of fibres within the maximum separation, the two slits were assembled separately then glued together before being polished on a spherically curved polishing plate. The aluminium plates used have a radius of curvature of 834.5 mm.

A small aluminium block with a piece of PTFE sheet glued to it forms a vice which holds the fibres in their respective grooves on the fibre slit. The grooves are cut with a CNC machine and are angled at approximately 6 degrees to the spherical surface. The grooves also are fanned out to ensure that they point correctly to the system pupil.

All the fibres are then inserted between the slit plate and Teflon surface, before epoxy glue is run into the inter-fibre spaces. After setting, the aluminium block and Teflon lift off easily to give the finished fibre-slit. After completing the second fibre slit, both halves are positioned together to within $500\,\mu$m and epoxy glue fixes the slit (Figure 4).

5. The cryogenic fibre slit

From the output fibres in the suppressor the fibre feed then runs to a strain-relief box attached to the outside of the cryogenic spectrograph. The fibres pass through a hole filled with vacuum-proof epoxy glue and into 56 cm loop of plastic conduit before forming a staggered output slit that is cooled with the rest of the optics to cryogenic temperatures.

Because of the limited number of pixels available on the PICNIC arrays, we had to pack the fibres as close together as possible. In order to overcome the buffer cladding, the fibres are in a staggered pattern that gives no inter-fibre gap on the array (Figure 6). This slit is unusual in that the fibres are in contact with the aluminium slit on one side but are supported on the other side by the two adjacent fibres.

To put in the fibres in this slit required thin plastic sheet between the two aluminium groove plates, and careful alignment of the grooves. The fibres were placed with the aid of an optical microscope.

Heating up the epoxy glue makes it cure in a shorter time, but makes the glue less viscous. We heated the fibre slit to 70°C and then added the hot glue—gravity and capillary action pulled the glue all through the fibre gaps. The slit surface was then cleaned of excess glue and the fibre-slit polished.

6. Performance and Conclusions

We have prepared four sets of fibre ends and they have successfully been mounted into three different types of fibre mounting—the techniques covered have involved curved surfaces with dual fibre slits, fibre alignment with lens arrays and staggered geometry fibre arrangements for use in cryogenic conditions.

The fibre feeds have all 100 fibres fully transmitting with none broken and no visible chipped fibre surfaces. After preliminary laboratory testing in the suppressor the dual slit feed was shown to be a complete success, the staggered fibre slit performed very well in the cryogenic spectrograph and the alignment of the fibres in the IFU have a positional accuracy of less than 5 microns, well within the tolerance of 10 microns stated in the design. COHSI will first be used in March 1998.

References

Piché F., Parry I.R., Ennico K., Ellis R.S., Pritchard J., Mackay C.D., McMahon R.G. *SPIE,* 2871, 1332 (1997)

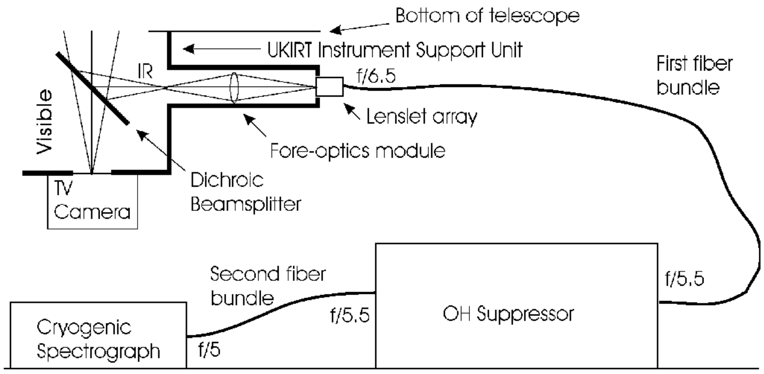

Figure 1. Layout of the various COHSI modules

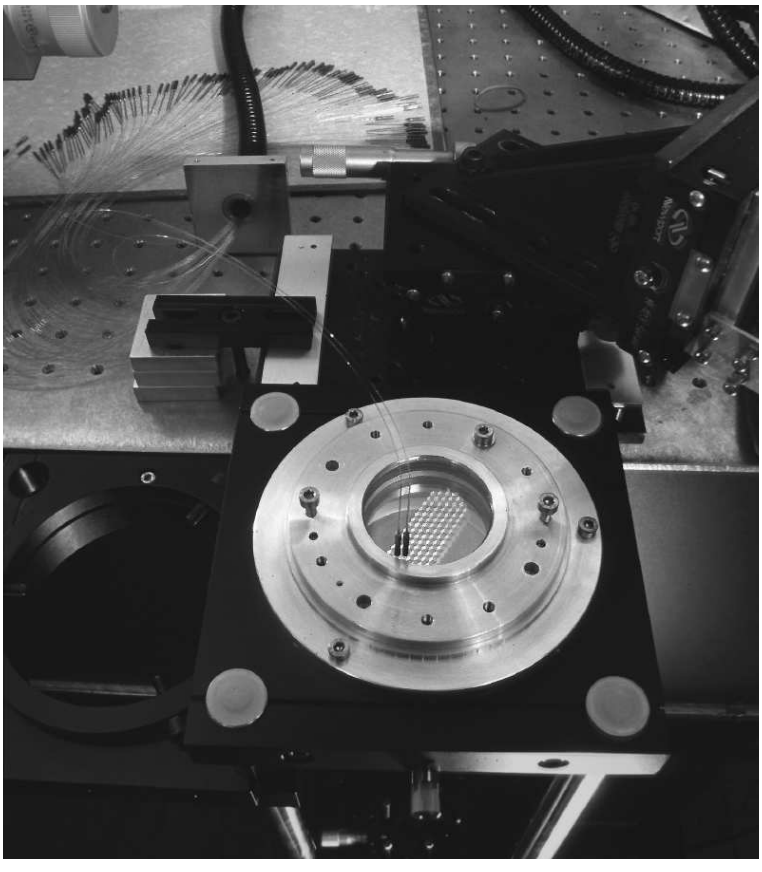

Figure 2. Fibre ferrules being placed onto the back of the lens array.

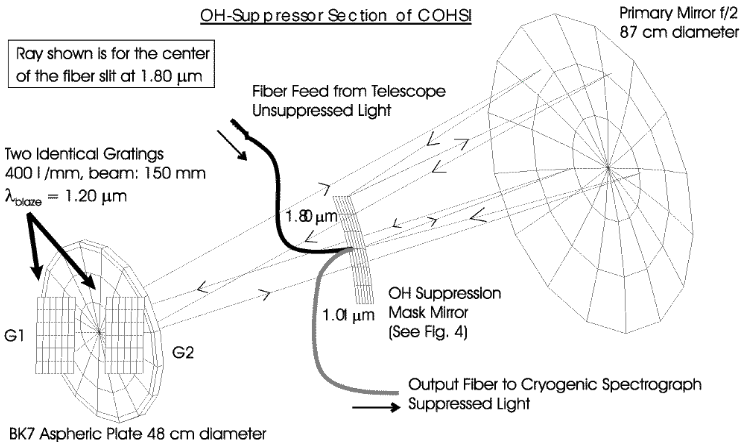

Figure 3. Position of the curved fibre slit in the suppressor.

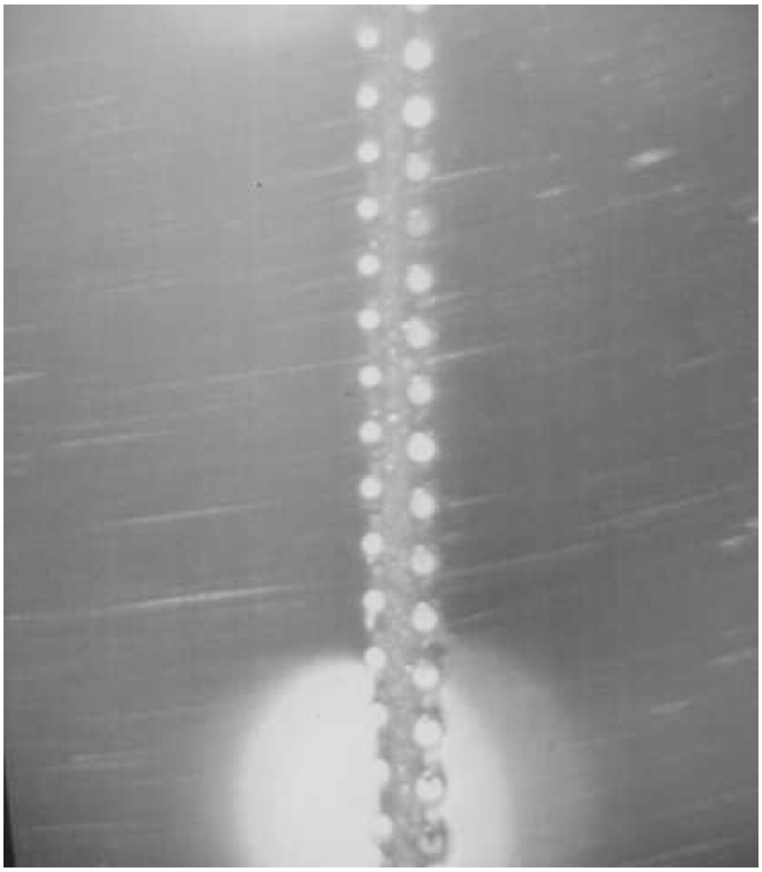

Figure 4. Illuminated fibres in the curved fibre slit.

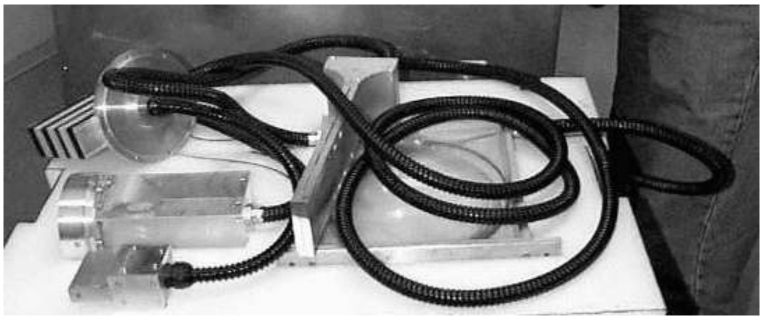

Figure 5. The completed fibre bundles.

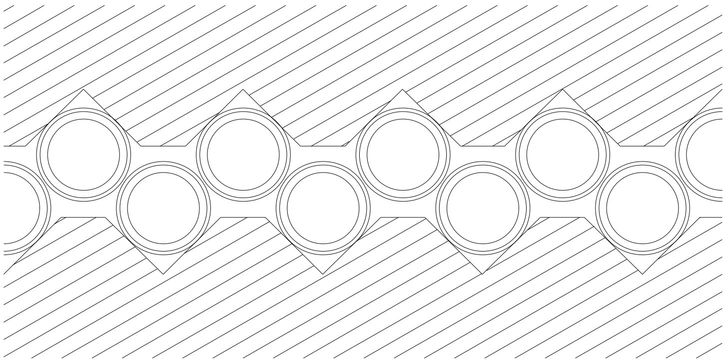

Figure 6. Schematic of the cryogenic fibre slit.