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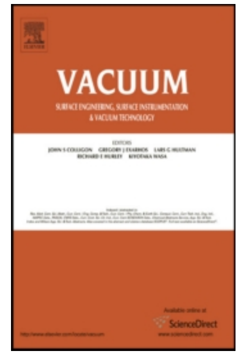

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Swagelok Ultra-Torr based feed-through design for coupling optical fibre bundles into vacuum systems

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Abstract

We report the design of an inexpensive and flexible fibre-optic bundle high vacuum feed through that can be constructed from easily available Swagelok Ultra-Torr™ stock parts. The fibre bundle extends through the vacuum envelope and thus does not suffer the transmission losses encountered when using face-to-face couplings. The flexibility of construction allows the fitting to be customised to suit all flange designs such as CF, KF or custom mountings. The use of Viton™ O-rings allows modest baking (max 200 °C) for high vacuum applications and fibre bundles can be easily repositioned, removed or replaced.

Key words: fibre-optic, feed-through, vacuum

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1 Introduction

Numerous analytical techniques require the transport of optical signals to be coupled through a vacuum envelope. Whilst designs for feed-throughs for single fibre optics have been discussed in the literature [1-3], to the authors' knowledge, feed-throughs that enable a continuous fibre-optic bundle to be passed through a vacuum chamber wall have yet to be developed. To this end, the most common method employs a pure silica core that is welded into a specific flange with the fibre optic elements being coupled to either end. Here, the fibre bundle is not continuous through the vacuum wall, leading to transmission losses in addition to limiting the user to a specific wavelength range.

The feasibility of utilising Laser Induced Breakdown Spectroscopy (LIBS) under vacuum conditions is currently being investigated in our laboratory. Spectral analysis of the extremely low light levels produced by the laser ablation events demands both optimisation of signal-to-noise ratio and minimisation of transmission losses. In order to investigate LIBS under vacuum conditions, a fibre-optic feed-through must be used that:

(1) enables flexible positioning of the fibre collection head to maximise collection efficiency
(2) is continuous ensuring no coupling interface transmission losses
(3) is vacuum tight.

To the authors' knowledge, there are no commercially available feed-throughs that meet these criteria. A number of systems have been described in the literature. Abraham and

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Cornell [1] describe a Teflon[1] feed-through using a 3.2mm Swagelok tube fitting connector suitable for UHV applications, but this is limited to single fibres with diameters of 120-160μm; scaling this design to a 12.7mm tube fitting did not allow UHV conditions to be attained. Miller and Moshegov [2] report the design and construction of an all metal UHV optical fibre feed-through, found to be leak tight to 10^{-9}cm^3/min helium when repeatedly baked to 250 °C. This feed-through design uses unmodified Swagelok tube fitting connectors and is, again, only suitable for single fibres (400 μm diameter plus aluminium jacket). A machined aluminium plug replacing the forward ferrule of the compression fitting provides the vacuum seal. Weiss and Stoever [3] describe an o-ring and epoxy sealed feed-through for optical fibre bundles. Their design preserves fibre continuity, is deemed to be rugged enough for field use and is easy to construct, but is fairly destructive in that it requires a length of the fibre bundle cladding to be cut away. Testing of this design on a 10 mm diameter fibre bundle yielded a base pressure ~ 10^{-4} mbar.

The objective of the present work is to design and commission an optical feed-through that fulfils the requirements above.

2 Fibre Optic Feed-through Design

To maximise the collected light intensity from the ablation plume, a fibre-optic bundle (Roper Scientific) is employed. The fibre bundle has a wavelength range of 190 to 1100

[1] Swagelok, Ultra-Torr, Viton, and Teflon are trade names that are used here for identification purposes and do not constitute an endorsement by the authors and their institution.

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nm, a collection angle of 25°, sheath diameter of 8mm and a steel collection head of diameter 10mm. The fibres comprising the bundle are sealed in epoxy at the collection head, the surface of which has a protective epoxy coating; as such there is no gas permeation along the fibres or fibre cladding into the vacuum envelope.

Fig. 1. Schematic of fibre-optic feed-through.

The feed-through design is based on standard easily available 'tried and tested' components, keeping in mind the design criteria outlined in the previous section. The use of stock parts enables the feed-through design to be easily tailored for a specific application. All components were ultrasonically degreased in solvent at room temperature prior to assembly. The feed-through is constructed using Swagelok Ultra-Torr 12.7mm (1/2 inch) fittings, shown in Figure 1 (top). This simple and effective design uses two unions, a convoluted tube of length 150 mm and a specially designed threaded aluminium plug (based on a standard fluid tube baseplate feed-through), which seals on the outer wall of the chamber with an elastomer o-ring and terminates in a nipple. The ends of the convoluted tubing are reinforced with Ultra-Torr XOA adapter cuffs. The Ultra-Torr unions are designed to accept 12.7 mm tubing; in order to create a vacuum tight seal around the 10 mm fibre-optic bundle head an o-ring of larger diameter than the stock Ultra-Torr o-ring was inserted; shown in Figure 1 (bottom). The use of convoluted tubing allows ease of manipulation and increased flexibility in positioning the fibre-optic bundle to optimise flux intensity from laser ablation of a given sample. Replacing the stock elastomer o-rings with Viton o-rings enables a gentle baking-out of the chamber (maximum 200 °C) to attain base pressures ~ 10^{-8} mbar.

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Fig. 2. Photograph of fibre-optic feed-through in-situ. The feed-through is secured through the base of the vacuum chamber and clamped in position; the collection end of the fibre-optic can be seen protruding through the clamp.

Figure 2 shows the constructed fibre-optic feed-through in situ. The vacuum chamber is a stainless steel bell jar with a volume of approximately 21 litres. With the feed-through in place the pump-down time and ultimate base pressure are unaffected. Helium leak checking with a residual gas analyser revealed no discernable leaks (RGA minimum detectable leak rate $< 7.9 \times 10^{-8}$ cm^3/min).

The design presented here has enabled LIBS investigations at low pressures. By way of example, LIBS preliminary data from silicon are presented in Fig. 3, showing a selected wavelength range of the emission spectra captured during laser ablation at atmospheric pressure and under vacuum conditions [4].

Fig. 3. LIBS spectra from Silicon under atmospheric and vacuum conditions

3 Conclusion

A design for an optical feed-through that can be used for general high vacuum systems has been described. The design may be easily adapted using stock Swagelok Ultra-Torr components to suit fibre-optic bundles of different dimensions.

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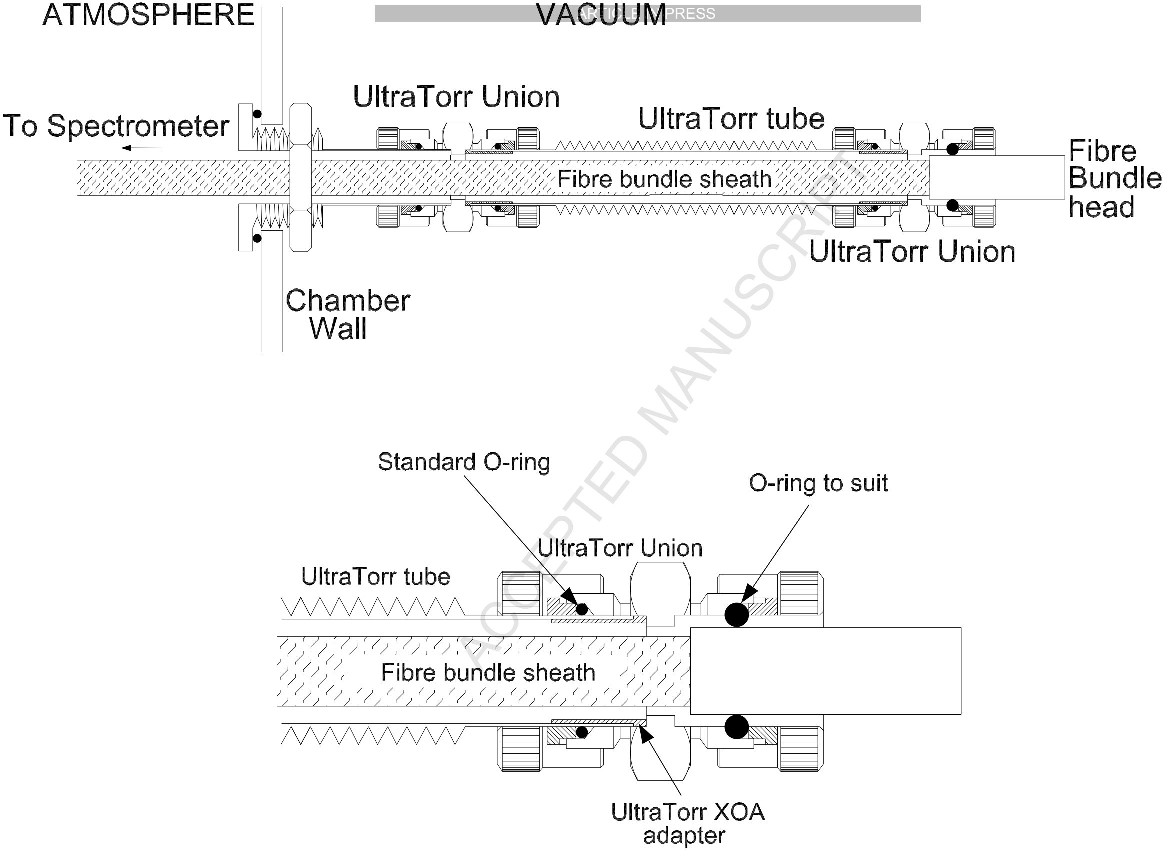

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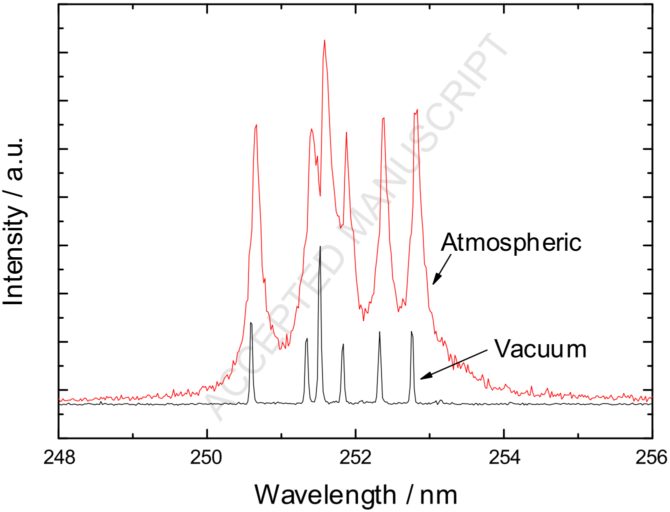

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