High vacuum feedthrough for angular, linear, and rotary motion

E. E. Scime, J. L. Kline, D. Mathess, and C. Weber II
Department of Physics, West Virginia University, Morgantown, West Virginia 26506

(Received 19 November 2001; accepted for publication 3 February 2002)

An angular motion feedthrough capable of supporting a large diameter linear motion feedthrough has been designed and built for the large experiment on instabilities and anisotropies at West Virginia University. With a combination of linear, angular, and rotary motion, a probe can be positioned in the vacuum chamber within a cone-shaped volume. © *2002 American Institute of Physics.* [DOI: 10.1063/1.1463696]

Spatially resolved measurements in large vacuum chambers require mechanisms capable of precisely moving probes in all three dimensions. Both internal motion systems and vacuum motion feedthroughs are used and each has advantages and disadvantages. Internal motion systems typically involve three axis motorized stages and a signal cable feedthrough for external control. Such systems yield accurate and reproducible motion, but typically occupy a significant fraction of the chamber volume and are incompatible with high temperature, high density, plasma experiments. Vacuum motion feedthroughs typically sacrifice full three-dimensional access for the advantage of externally mounted motors and survivability in harsh environments.

Our plasma physics experiments are performed in a large vacuum chamber (2-m diameter by 4-m long). Rather than install a large, internal, three axis motion system, we chose to construct a vacuum motion feedthrough capable of providing access to at least one-half of the vacuum chamber. To reach across the axis of the chamber and 2 m of the chamber's length, the feedthrough must be able to support a rigid shaft at least 2-m long and be able to tilt through a wide range of azimuth and polar angles. Because the probe head includes a number of different diagnostics, the shaft also has to have an inner diameter large enough to permit the passage of two fiber optic cables and four signal cables. During the design of our feedthrough, a number of issues were considered: reliability, cost, complexity, range of motion, and shaft diameter. The long shaft length required to meet our spatial access requirements was the critical factor. Small diameter stainless steel shafts, under 0.5 in., with thin walls are not rigid enough to span 2 m without substantial bending. The structural strength and large bore constraints forced us to choose 0.75-in.-diam stainless steel pipe with 0.063-in.-thick walls for the probe shaft.

Angular motion vacuum feedthroughs fall into two general categories, those that use a rigid sealing surface and permit angular deflection through the use of bellows[1,2] and those that use a sealing surface that pivots within the seals, i.e., a differentially pumped bearing captured between two circular seals.[3,4] In bellows-based feedthroughs, the linear motion of the probe shaft is accomplished through a differentially pumped sliding seal mounted on the end flange of the bellows. With sliding bearing seals, the probe shaft must pass through the bearing. Thus, the bearing must have a diameter at least as large as the probe shaft. To achieve a significant angular range with a sliding bearing seal, the bearing diameter must be much larger than the probe shaft diameter. Because bearings large enough to provide ±35° of angular motion for a moving 0.75-in.-diam probe shaft are difficult to obtain commercially, we chose to design our feedthrough around a commercially available welded metal bellows. Bellows-based feedthroughs do have higher costs and a limited number of bending cycles, but the large probe shaft diameter and large angular range requirements could only be met with a bellows-based design.

The essential elements of the angular motion support are shown in Fig. 1. A 1-in.-o.d. stainless steel shaft with 0.083-in.-thick walls is supported in a commercially available, stainless steel ball joint bearing. The bearing is captured in a stainless steel ring that is supported on a 1/2-in. threaded shaft. The ring is free to rotate around the axis of the threaded shaft and the ball joint bearing is located at the center of the bellows to provide for the maximum possible range of angular motion. Stainless steel, linear motion bearings for the 0.75-in. shaft are coupled to both ends of the support shaft to provide alignment and support for the probe shaft. The linear motion bearings provide critical mechanical support of the heavy probe shaft as it moves through the linear double O-ring seal shown in Fig. 2. Without the linear motion bearings, bending of the heavy probe shaft causes scoring of the shaft as it passes through the double O-ring seal. For the view shown in Fig. 1, angular motion in and out of the plane of the page is completely unrestricted. This angular direction corresponds to scanning along the axis of the large vacuum chamber. Angular motion in the plane of Fig. 1 (up and down) is restricted by the range of motion of the ball joint bearing and the design of the support bracket. To increase the range of angular motion in the plane of Fig. 1, the nearby corner of the support bracket could be machined at a more appropriate angle. Note that the outside of the linear motion bearing housing to the left of Fig. 1 is threaded for mounting in the flange with the linear double O-ring seal in Fig. 2.

The essential elements of the vacuum seal are shown in Fig. 2. The large mounting flange supports the mass of the feedthrough and the probe shaft. Not shown in Fig. 2 are the

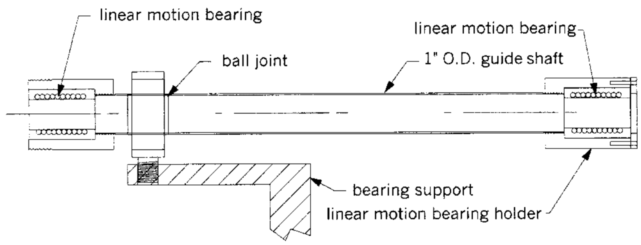

FIG. 1. Mechanical drawing of the ball joint bearing and guide shaft assembly. The principle direction of angular motion is in the plane normal to the drawing.

off-center line slots and bolts in the bearing support bracket for attachment to the main flange. The mounting flange aperture in which the bearing rotates is conical in shape and allows the probe shaft to move approximately ±35° in the plane in and out of Fig. 2. As noted previously, the probe shaft can traverse approximately ±15° in the plane of Fig. 2. The most expensive component of the feedthrough is the oversized welded bellows connecting the mounting flange to the flange containing the double O-ring linear motion feedthrough. The linear motion feedthrough is a standard 3/4-in. Cajon™ fitting that has been modified to permit the insertion of two O-rings separated by a small intermediate vacuum region. The space between the O-rings is evacuated through a 1/4-in. pump out port welded into the side of the Cajon™ fitting.

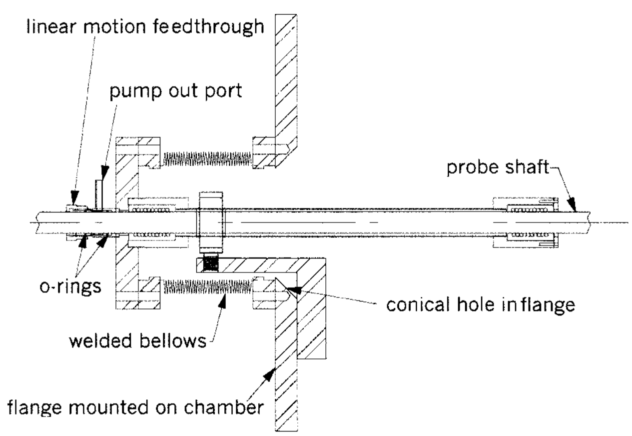

FIG. 2. Mechanical drawing of the entire angular motion feedthrough assembly. The vacuum seal is made on the probe shaft at the linear motion feedthrough with a differentially pumped double O-ring seal. The exterior end of the probe shaft is terminated in a small, sealed chamber with optical and electrical feedthroughs.

To control the motion of the probe shaft in our experiments, we have attached two linear and one rotary VELMEX™ stepping motor assemblies to the nonvacuum end of the sealed probe shaft. The rotary stepping motor spins the probe shaft around its axis for optical tomography experiments.[5] The two linear stepping motors control the insertion depth of the probe shaft and the feedthrough angle in the plane defined axis of the chamber and a single azimuthal angle, i.e., from one port in the side of the chamber the probe can scan through a horizontal plane that includes the axis of the chamber. The shape of the plane that can be accessed is triangular and includes over 2 m of the length of the chamber on axis. The ±15° angular range in the plane normal to the scanning plane is only used for final alignment of the probe with respect to the axis of the chamber. With the stepping motors, the probe head can be accurately positioned to within 1 mm of the desired radial and axial locations. Without the 1-in. guide shaft with the linear motion bearings, the stepping motors would be unable to insert the probe without scoring the probe shaft and thereby degrading the vacuum integrity of the feedthrough. With Viton™ O-rings, the typical base pressure of 1×10^{-7} Torr in the large vacuum chamber is unaffected by this angular motion feedthrough.

This work was supported by National Science Foundation Grant No. ATM-99988450.

[1] S. H. Begemann and J. Eilander, J. Phys. E **4**, 660 (1971).
[2] J. Eilander, H. H. Feijen, S. B. Luitejens, and E. P. Th M Suurmeijer, J. Phys. E **9**, 814 (1976).
[3] A. M. Ferendeci, J. Phys. E **6**, 818 (1973).
[4] D. Leneman and W. Gekelman, Rev. Sci. Instrum. **72**, 3473 (2001).
[5] E. E. Scime, P. A. Keiter, S. P. Gary, M. M. Balkey, R. F. Boivin, J. L. Kline, and M. Blackburn, Phys. Plasmas **7**, 2157 (2000).