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Poster paper

Mechanical design and fabrication of a two-blade stripline for the Advanced Photon Source storage ring

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The storage ring tune measurement system at the Advanced Photon Source (APS) consists of signal pickup and beam excitation drive striplines. Striplines currently installed in the APS storage ring are of a four-blade (inner conductor) design that serves as a beam diagnostic tool and for transverse and longitudinal tune measurements. A new two-blade stripline was designed for the transverse feedback system and to be used for horizontal beam excitation. In this paper, we discuss its mechanical design, assembly procedure, and construction.

1. Introduction

The most commonly used transverse feedback kicker consists of a pair of 50 Ω transmission lines or striplines built into the beampipe and powered in balanced transverse electromagnetic (TEM) configuration (Winick). The four-blade design has inner conductors which are 2.0 mm thick and 171.5 mm long connected to hermetically sealed 50-Ω Radio frequency (Rf) feedthroughs. The new two-blade stripline has 1.50-mm-thick and 358.5-mm-long inner conductors with elliptical cross-section geometry. The electrodes and feedthroughs, as shown in figure 1, form a 50-Ω transmission line when connected together with the 0.01-mm-thick L-shaped clips. The design goal is to produce a stripline with an overall impedance of 50 ± 5-Ω. In anticipation of impedance mismatches resulting from machining errors, components configuration and assembly and welding, a cold test measurement system was designed.

2. Design and fabrication

The stripline design was optimized for a 50-Ω match in the electrode geometry and in the clip transition to the feedthroughs. The ends of the electrodes, as shown in figure 2(*b*), were tapered from the finished 94° to 55.8° over 50.0 mm length to produce a 50-Ω match with the taper transitions. The geometry, length and thickness of the electrodes were the most challenging to be machined and required extra effort in an attempt to achieve a 0.18–0.25 mm straightness tolerance.

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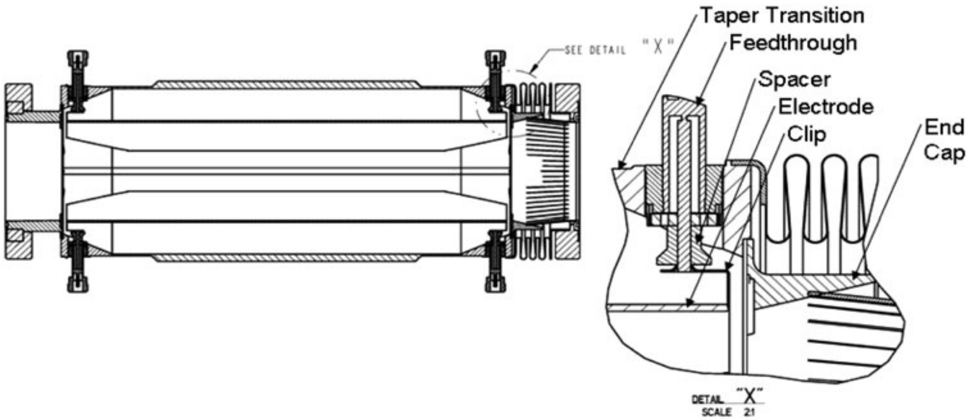

FIGURE 1. Cross-section of the two-blade stripline illustrating the components configuration.

End caps were designed to close off the two-circle aperture in the body design allowing for a gradual transition from the two-blade ellipse to the storage ring beam chamber aperture, shown in figure 2(*a*). Coupling of the electrodes to the feedthroughs is accomplished by the use of 0.25-mm-thick L-shaped 316L stainless steel clips that also serve as strain relief from forces acting on the feedthrough centre conductor. The body, tapered transitions and electrodes were machined from 316L stainless steel, using a wire electrical discharge machining process.

The 50-Ω, ultrahigh vacuum, type-n, microwave feedthroughs used are from Meggitt Safety Systems (No.853831-001). The outer body is 304 stainless steel, and the centre conductor is Titanium, Zerconium, Molybdenum alloy (TZM molybdenum). The centre conductor measures 2.64 mm in diameter and is machined down to approximately 1.0 mm diameter at the point where it is brazed into the vacuum seal ceramic. This design is more suited to axial loading and not transverse loading as is required in this stripline design. The 358.5-mm-long electrodes were initially 3.0 mm in thickness and each weighed 555 g. Analyses of shear stresses in the centre conductor as a result of this load applied at a distance of 33.0 mm from the fixed end showed Von Mises stresses of 958 MPa in the 1.0 mm diameter. The assumed yield stress used for TZM molybdenum was 810 ± 43 MPa. Using two feedthroughs per electrode did not produce a robust design; hence it was necessary to reduce the weight of the electrodes, as well as to support the centre conductor. The thickness of the electrode was changed to 1.5 mm, reducing its weight to

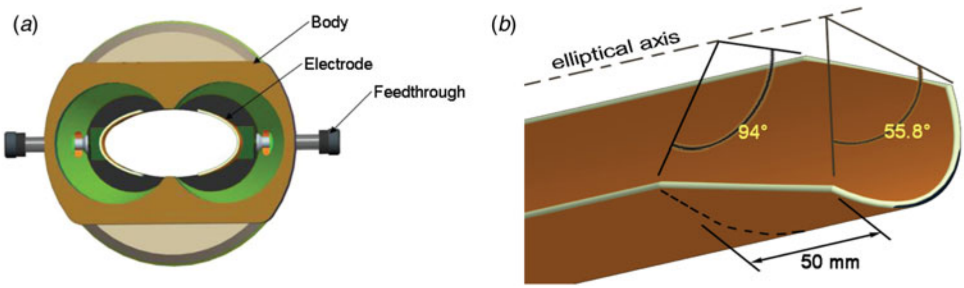

FIGURE 2. (*a*) Body and blade configuration. (*b*) Blade end-taper.

266 g. A support for the centre conductor, shown in figure 3, was designed and placed close to the point where the electrode is connected to each feedthrough. This support device is made from fused silica ceramic brazed into 304 stainless steel. Fused silica was selected because of its low relative dielectric constant of 3.8 at 1 MHz. The diameter of the fused silica disc to produce a 50-Ωimpedance match with the feedthrough was determined as follows:

$$Z_0 = [138/(\varepsilon_r)]^{1/2}\ [\log(D/d)]\ \Omega$$

where $Z_0 = 50\ \Omega$, ε_r is the relative dielectric constant of the ceramic, D is the diameter of the ceramic disc and $d$is the diameter of the feedthrough centre conductor (Van Valkenburg 1995).

3. Assembly and testing

The stripline is an assembly weldment that leaves little room for error during the weld process. Hence, care was taken to test and measure for impedance mismatches of each subassembly. Component parts were cleaned prior to assembling and handled with proper gloves throughout all phases of the assembly. The adapter, shown in figure 3, was tungsten inert gas (TIG) welded to the feedthrough and vacuum leak checked. The centre conductor support was then e-beam tack-welded to reduce residual stresses and cracks in the silica ceramic. Utilizing the cold test fixture setup and an Agilent Infiniium DAC-1 86100C Network Analyzer configured as a time domain reflectometer (TDR), 70-Ω impedance bump in the clips-to-feedthrough transition was revealed. Careful analysis determined that a spacer was needed to bridge the gap between the back of the clip and the silica ceramic. The feedthrough assembly was tack-welded to the tapered transition and the clip e-beam brazed to the molybdenum centre conductor using a 72/28 Cu/Ag alloy paste. Further cold testing showed impedance measurements below the 45-Ω low limit. Analyses revealed that the silica ceramic had been metallized with vapour from the alloy. Tuning to the 45–55 Ω was achieved by carefully removing the metallized layer. Additional cold test setups revealed mismatches of 60-Ω in the tapered sections of the electrodes. These were resolved by welding 2.4 mm × 17.5 mm long strips on the edges along the taper. End caps were assembled, welded and leak checked. To complete the assembly, bellows and flanges were added and the TIG welded in place. The stripline was vacuum-certified and characterized

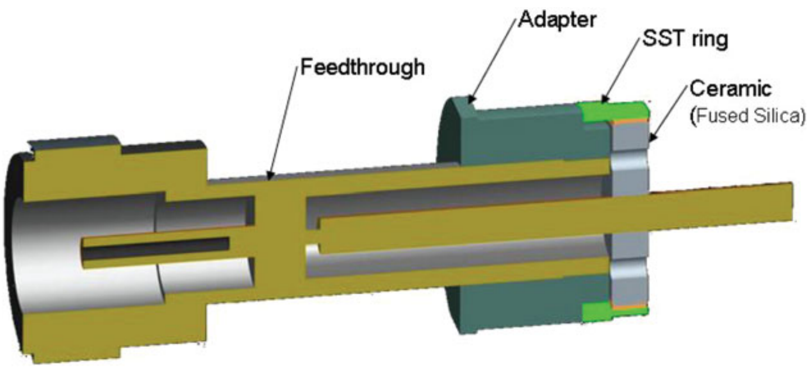

FIGURE 3. Feedthrough cross-section showing centre conductor support.

using an Agilent Technologies E8362B Network Analyzer to measure port isolation and reflection.

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