SPEAR 3

Technical Specification for

Procurement of a Button-Style 50 Ohm

Beam Position Monitor Feedthrough

PS-444-326-01 R0

Approved:

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Stanford University
Stanford Synchrotron Radiation Laboratory

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1.0 Introduction

This specification governs the design, fabrication, performance, testing, acquisition, and delivery of the button style beam position monitor feedthroughs BPM's for the SPEAR 3 project at the Stanford Synchrotron Radiation Laboratory (SSRL), a part of Stanford University, hereinafter referred to as the University. The electrical feedthrough assemblies are for high frequency, high accuracy measurements of beam position in the vacuum system of the SPEAR 3 Storage Ring.

2.0 Applicable Documents

The applicable documents listed below are a part of this specification. In the event of a conflict, the contents of this specification shall take precedence over the documents referenced herein.

2.1 SSRL Drawing

a. SSRL Drawing SC-444-315-01, - "SSRL – SPEAR 3 Girder Chamber 50Ω 1.2cm Button BPM,"

2.2 Stanford Linear Accelerator Center (SLAC) Specifications

a. SLAC Specification PS-202-100-02, - "Alumina Bodies for Ceramic to Metal Seals and UHV."

b. SLAC drawing No. SC-700-866-47, - "Specification; Machining Lubricants...."

2.3 Military Specification

a. MIL-C-390 12 Connectors, Coaxial, Radio Frequency, General Specifications.

b. MIL-G-45204C (2) Gold Plating, Electrodeposited.

2.4 Commercial Specifications

a. QQ-S-763E, "Steel Bars...Corrosion Resisting."

b. Dimensioning and Tolerancing ASME/ANSI Y 14.5M - 1982.

c. Electron-Beam Welding, SAE/AMS 268 1.

d. Laser Beam Welding. AWS WHB-2, Chapter 22.

e. Standard Specification for Copper-Beryllium Alloy Rod and Bar ASTM B 196.

f. Cupronickel, Varian Specification P3-10, "Cupronickel All Forms."

g. Standard Specification for Molybdenum and Molybdenum Alloy Bar, Rod. and Wire ASTM B 387.

h. Determining the Inclusion Content of Steel ASTM E-45.

3.0 Requirements

3.1 General Requirements

The University requires that the Seller be responsible for assurance that the feedthroughs meet all the requirements of this specification. Inspection and approval of procedures and records by the University does not alter that responsibility in any way. No deviation from this specification or those stipulated herein shall be permitted without prior written permission by the University, including alternatives specified as "University Approved Equal."

3.2 General Description

The button feedthrough is a precise and rugged electromagnetic sensor, which transmits signals from the ultra high vacuum (UHV) chamber to air.

3.3 Mechanical Requirements

The feedthrough layout drawing, #SC-444-315-01, provides external dimensions necessary for assembly into the vacuum chamber. The drawing suggests an internal design that achieves a 50 Ω impedance, and is to be used as a guideline for alternative designs as determined by the Seller. It is the responsibility of the Seller to ensure the electrical characteristics of the feedthrough as described in section 3.4 of this document. Furthermore, the layout drawing is not intended to establish the manufacturing process of the feedthrough. It is the Seller's responsibility to determine the manner of operation to assemble the feedthrough while maintaining the mechanical and electrical reliability as specified in this document.

3.3.1 Ultra High Vacuum, Leak Integrity

The feedthrough will be used in an Ultra-High Vacuum (UHV) environment of 10^{-10} Torr. The feedthrough's vacuum sealing surfaces shall be leak tested as specified in section 4.6.1.1.

3.3.2 Fabrication and Handling

All lubricants, cutting fluids, etc., used in manufacturing must be "sulfur-free". Seller shall provide the University representative with all information needed to identify the source and constituents of all fluids and lubricants used. SLAC document No. SC-700-866-47 is a compendium of the University approved lubricants. The use of sanding discs, abrasive paper or grinding wheels is prohibited unless prior written approval is obtained from the University.

All parts and subassemblies shall be cleaned for UHV. Once parts are cleaned for vacuum, handle only with clean polyethylene gloves in a clean room on clean surfaces. This includes all subassemblies handled by the Seller or any subcontractor of the Seller. For storage or transportation, wrap with new lint-free tissue and vacuum grade aluminum foil and place in a clean sealed container, or University approved equivalent packaging method. The final part is not recleanable for UHV, and therefore shall be delivered free of visual contamination and clean for vacuum. If any evidence of hydrocarbons or other high vapor pressure contaminants are measured in UHV at 150°C per section 4.7.1.6 of this specification, this shall constitute cause for rejection.

3.3.3 Materials

All parts and materials for the feedthroughs shall be new and compatible with the performance requirements of this specification. The materials for the feedthroughs must be those designated by SSRL drawings and this specification or a University approved equivalent. Mil source certifications, including heat number, chemical analysis for all materials used in the manufacturing of the feedthroughs shall be furnished per Section 4.4 of this specification. The feedthrough will be used in a radiation environment with a maximum rate of about fifty megarad per year, and a total integrated dose of 10^9 rad. All materials shall be consistent with this application. Use of Teflon is specifically prohibited.

3.3.3.1 Cupronickel

All Cupronickel or Copper-Nickel parts shall be made from certified seamless Modified Type UNS-C71580 70/30 Cupronickel, electronic grade round stock, containing less than 0.50% Fe, 0.01% Pb and

0.05% Zn. The Cupronickel shall be compliant with Varian Specification P3-10,"Cupronickel All Forms."

3.3.3.2 Stainless Steel 304L

All stainless steel parts shall be made from certified argon-oxygen decarburized (AOD) and vacuum induction melted (VIM), vacuum arc remelted (VAR), or electro-slag remelted (ESR), AISI type 304L stainless steel per the applicable sections of QQ-S-763E. The University requires that the chosen method require a secondary refining process in addition to the AOD. The inclusion content shall not exceed a maximum of 1.5 Heavy and 2.0 Thin for inclusion types B, C, and D described in method D of ASTM E-45.

3.3.3.3 Ceramic

The ceramic shall be a minimum of 97% aluminum oxide having a maximum dielectric constant of 9.58 or borasilicate glass loaded with alumina having a maximum dielectric constant of 4.6. The alumina shall be in accordance with the applicable sections of SLAC Specification PS-202-100-02. The mechanical properties of the alumina borasilicate glass at 20°C shall be consistent with the values listed in table 3.3.3.3.

Table 3.3.3.3

PARAMETER	LIMIT
Loss Tangent	0.0026
Dielectric constant	4.9
Thermal Conductivity	10 W/m-K
Thermal expansion coefficient	4-6 x 10^{-7} /°C
Modulus of Elasticity	8.2 x 10^{6} psi
Poisson's Ratio	0.22
Designed Compressive Strength	35,000 psi
Designed Tensile Strength	3000-6000 psi

3.3.3.4 Molybdenum

All molybdenum shall be made from certified vacuum arc cast Molybdenum Alloy 365, TZM Molybdenum Alloy 363 or University approved equivalent. The materials shall be consistent with ASTM B 387.

3.3.3.5 Other Materials

Filler materials or intermetallic buffers shall be allowed. All alloys must be non-magnetic with a relative permeability less than 1.05 at 200 oersteds (air equal to 1.0) when measured by a Severin Standard Ferrite Indicator.

3.3.4 Ceramic-to-Metal Assembly

The ceramic-to-metal assembly shall be brazed in a dry hydrogen furnace using a University approved alloy for preparation and brazing. The University approval of the brazing method and brazing material in no way relieves the Seller from responsibility to meet all requirements of this specification. All plating materials must be University approved. The ceramic-to-metal assembly shall be in accordance with the applicable sections of SLAC Specification PS-202-100-02.

3.3.5 Connector and SMA Protection

The air side of the feedthrough shall be a SMA compatible Jack connector (hereafter SMA connector). The SMA connector shall be in accordance with the applicable portions of MIL-C-39012/81, "Connectors Coaxial, Radio Frequency, Series SMA." The SMA connector shall be protected from mechanical damage by a removable shroud threaded to the device body.

3.3.6 Center Conductor

The center conductor of the connector shall be beryllium-copper per ASTM B 196, Alloy C 17300, Condition H, HT, HM, HTR, HTC, or a University approved equivalent. The center conductor must have sufficient spring force to make a firm and reliable contact with the center pin of the mating plug per the applicable sections of MIL-C-39012/81. The center conductor must be gold plated in the area of electrical contact with the connector pin per MIL-G-45204. Also, the center conductor shall be fixed to the feedthrough pin to ensure that the center conductor does not separate when disconnecting the mated SMA connectors.

3.3.7 Service Life

The expected service life of the electrical UHV feedthroughs is 30 years.

3.3.8 Environmental Requirements

Feedthroughs must operate at a normal service temperature of 100°C and a relative humidity up to 80% water vapor. Fluctuations in temperatures will be due to changes in ambient air temperatures and from periodic shut downs during operations.

3.3.9 Thermal Cycling

The feedthrough's shall be capable of 50 vacuum bakeouts at 250°C as described in section 4.6.1.1 of this specification, and thermal cycling from

20°C to 200°C for 10,000 cycles as described in section 4.7.1.3 of this specification.

3.3.10 Thermal Shock

Feedthroughs will be subjected to thermal shock tests by the University as described in Section 4.7.1.3 of this specification.

3.4 Electrical Requirements

3.4.1 Summary of Electrical Requirements

Electrical requirements of the Button Feedthrough are summarized as shown in Table 3.4.1 and are as described herein.

Table 3.4.1

PARAMETER	LIMIT
Equivalent Circuit	Z0=50Ω, $\tau < 100$ ps electrical length C=1.6 – 2.0 pF, nominal
50 Ω Coaxial Line Bandwidth	DC – 20 GHz (-6 dB)
Reflection Coefficient	$\rho < 0.05$
Button Capacitance	1.6 – 2.0 pF nominal, within 0.16 pF window
DC Resistance	< 8 m Ω
DC Leakage Resistance	> 10^9 Ω at 500 VDC
Voltage Breakdown	> 1000 Volts rms 60 Hz
Power Handling	5 W heating with 50 W CW incident, at 5 GHz
Impedance	See Par 3.4.11
Electromagnetic Interference	MIL-C-39012/81

3.4.2 Electrical Equivalent Circuit

The Button Feedthrough Equivalent Circuit shall be defined by a nominal 50 Ω coaxial transmission line of less than 100 ps electrical length, terminated in a nominal lumped capacitance between 1.6 pF and 2.0 pF. Connection to the circuit shall be made through a SMA connector. The SMA connector shall be in accordance with the applicable portions of MIL-C-39012/81, Connectors, Coaxial, Radio Frequency, Series SMA. Design features incorporated from the 3.5 mm coaxial connector interface are acceptable.

3.4.3 50Ω Coaxial Line Bandwidth

The 50 Ω Coaxial Line and any associated tapering sections shall have a 6 dB bandwidth exceeding 20 GHz.

3.4.4 Reflection Coefficient

The Reflection Coefficient (ρ) shall not exceed 0.05 when measured using a 17 picosecond or less risetime pulse and a 20 GHz or more measurement bandwidth, exclusive of the button itself.

3.4.5 Button Capacitance

The nominal capacitance of the Button to the Feedthrough Body, excluding the capacity of the 50 Ω Coaxial Line, shall be between 1.6 pF and 2.0 pF. The variation of unit-to-unit capacitance measured shall be within a 0.16 pF window.

The nominal capacitance of the entire unit shall be between 3.0 pF and 3.4 pF. The variation of unit to unit capacitance measured shall be within a 0.16 pF window.

3.4.6 DC Resistance

The DC Resistance measured through the SMA connector and a mating Plug connector, to any point on the button, shall not exceed 8 mΩ after completion of the contact and connector durability tests specified in MIL-C-39012/81, Sections 4.7.12 and 4.6.13.

3.4.7 DC Leakage Resistance

The DC Leakage Resistance of the Button Feedthrough, measured from the Button to the Feedthrough Body, shall exceed 10^9 Ω when tested up to a 500 Volt DC potential.

3.4.8 Voltage Breakdown

Voltage breakdown at the button end shall not occur under application of 1000 VAC rms (60 Hz) through the SMA connector, mated and fully engaged to a suitable SMA plug, at both 1.0×10^{-8} Torr, and 760 Torr. Voltage breakdown shall not occur with an atmospheric pressure of 760 Torr at the SMA interface.

3.4.9 Power Handling

Application of 50 W CW at 5 GHz shall not produce internal heat dissipation (Transmission Loss) exceeding 5.0 W (Loss Factor <0.46 dB). Transmission Loss is defined as one half the measured loss in signal level of two button feedthroughs electrically connected through the buttons, i.e. "double-ended" or "back-to-back", and excited through the SMA connectors. Transmission loss shall by definition exclude reflection loss. Failure of the vacuum seal shall not occur as a result of internal heat dissipation, up to and including 5.0 Watts internal dissipation.

3.4.10 Impedance

The BPM Button removes real and reactive power from the passing particle beam, and constitutes an electrical impedance. The University will evaluate the Seller's proposed design by numerical analysis of the Seller's fabrication or assembly drawings, which shall be supplied to the University before fabrication. The University will measure the impedance parameters of the Seller supplied feedthroughs to determine compliance to the impedance requirements

3.4.10.1 Broadband Impedance

The broadband impedance caused by the BPM button is determined by the button geometry, vacuum chamber cross-sectional geometry, and the placement of the buttons in the chamber. The SPEAR3 chamber geometry and button placement is determined by accelerator requirements. The major contribution of broadband impedance by the BPM button is due to the gap between the button and its housing. Simulations performed by the University have shown that the button design shown in drawing SC-444-315-01, assembled in the SPEAR3 vacuum chamber produces an inductive impedance of 57 $\mu\Omega$ at the accelerator revolution frequency of 1.28 MHz. The broadband impedance of any alternative design presented by the Seller may not exceed 63 $\mu\Omega$ at 1.28 MHz for the same chamber cross-section and button placement. The University shall calculate the broadband impedance due to any design change to determine if the proposed design meets the requirements of this specification.

3.4.10.2 Narrowband Impedance

The Narrowband Impedance is associated with resonant non-TEM modes which may be present in the BPM Button. The Narrowband Impedance shall not exceed the limits specified in Table 3.4.10.

Table 3.4.10	
Frequency Range	**Real (Z)**
DC – 8.0 GHz	< 4.0 Ω, no narrowband impedance below 8.0 GHz
8.0 GHz – 10.0 GHz	< 8.0 Ω
10.0 GHz – 15.0 GHz	< 10.0 Ω

3.4.10.3 Transfer Impedance

The Transfer Impedance is defined as the impedance that when multiplied by the beam current, yields the voltage developed at the SMA connector, loaded in 50 Ω. The nominal magnitude of the Transfer Impedance shall be within 0.55 Ω- 0.70 Ω at 476 MHz.

3.4.10.4 Electromagnetic Interference

The EM1 leakage at engaged Plug and Jack SMA connectors shall not exceed the limits allowed in MIL-C-39012 for SMA connectors.

4.0 Inspection, Test Provisions, Quality Assurance

4.1 Source Inspection

The University reserves the right to perform source inspections with proper notification at the Seller's facility of all materials, parts, subassemblies, assemblies, manufacturing, testing and inspection required for this contract.

4.2 Quality Program/System Requirement

The seller shall provide and maintain a quality program/system that complies with a recognized U.S. Quality Program/System standard in effect on the contract date. Examples of such programs include: ISO 9001; MIL-I-45208; ASME Boiler and Pressure Vessel Code, Section VIII, Appendix 10; or ANSI N45.2.

The Seller shall require, in writing, subcontractors to comply with all applicable quality program/system requirements. The quality system and control of special processes of the Seller and subcontractors shall be subject to review by the Buyer to the extent practicable at all times and places.

The Seller shall tender for acceptance only those supplies or services that have been inspected and tested in accordance with its quality program/system and have been found to conform with contract requirements.

4.3 Serial Numbers

Each feedthrough shall have a serial number assigned to it. The serial number shall be permanently engraved on the exterior of the non-vacuum side of the feedthrough body as depicted on drawings SC-444-315-01. Any sequential numbering system is acceptable.

4.4 Material Certification

Seller shall furnish original source test certifications of all materials that are a part of the finished product. Material for which no certifications are available shall not be used in any part of the BPM feedthrough.

Certifications must be copies of the original physical and chemical test reports from the mill source of the ingot or billet. Ordinary "Certifications" retyped on suppliers' forms are not acceptable.

4.5 Acceptance Tests, Final Acceptance

Acceptance testing shall be performed by the Seller to verify that the feedthroughs supplied under the contract meet the requirements of this specification. Prior to testing, a concise description of the testing and inspection procedure shall be submitted for University approval. Acceptance or approval of material during the course of manufacture shall not be construed as a guarantee of its acceptance in the finished product. All articles shall have satisfactorily passed the acceptance tests specified in section 4.6 prior to delivery. Evidence of noncompliance with the above shall constitute cause for rejection of the entire lot. Notwithstanding the inspection requirements at the Seller's plant as described herein, final acceptance of all feedthroughs shall take place following delivery to and testing by the University.

The University reserves the right to perform any or all tests which would be required to verify that the feedthroughs delivered conform to the requirements of this specification. Units that fail any of the tests performed will be deemed unacceptable and the entire lot will be returned to the Seller for replacement at no cost to the University. The Seller is responsible for incorporating any configuration changes if it is determined that the failure is caused by a design or manufacturing flaw. The Seller's responsibility includes cost of shipping, labor and materials.

4.6 Tests Performed by the Seller

The following tests shall be performed at the Seller's facility. Failure of these tests shall be grounds for rejection. The Seller is responsible for incorporating any configuration changes if it is determined that the failure is caused by a design or manufacturing flaw. The Seller's responsibility includes cost of labor and materials.

4.6.1 Mechanical/Vacuum

4.6.1.1 Leak Test

Leak testing shall be performed on all deliverable assemblies. The leak test shall be performed on the air side of the feedthrough if an oil-less leak detector is not used. The sealing surfaces shall be leak tested with a helium mass spectrometer leak detector calibrated to a minimum sensitivity for helium of 2×10^{-10} std cc/set. Probe with helium for one minute and reject any part with a leak rate of 2×10^{-10} std cc/sec above background. O-rings or rubber flat stock used, as a temporary seal for the purpose of leak testing shall be new rubber, clean and dry. A minimum film of electronic grade alcohol may be used at the sealing surface to rubber interface as a temporary seal. The use of lubricant or grease is prohibited.

4.6.1.2 Dimensional Measurements

Dimensions of the feedthrough assembly shall be measured for conformance to the drawing requirements on SC-444-315-01, note #8.

4.6.1.3 Acceptance Test Data

The Seller shall include acceptance test data with each certificate of conformance. Each report shall identify the unit by serial number, and shall be signed by an authorized representative of the Seller.

4.7 Tests Performed by the University

In addition to the acceptance tests performed at the Seller's facility, the feedthroughs will be acceptance tested at the University.

4.7.1 Mechanical/Vacuum

4.7.1.1 Leak Test

Leak test per section 4.6.1.1.

4.7.1.2 Bake Out

Vacuum bakeout at 250°C for 5 days.

4.7.1.3 Thermal Shock/ Thermal Cycling Testing

One or both of the following test will be performed.

Thermal Shock Test

The feedthrough will be heated to 250°C for 30 minutes and have liquid nitrogen or ice water poured into the top of the SMA connector. This will be repeated for 20 cycles. A vacuum leak test as described above will be performed after 1 cycles, 10 cycles, and 20 cycles.

Thermal Cycle Test

Heat button and/or center pin to 200°C and cool down to ambient via natural convection for 200 cycles.

4.7.1.4 Dimensional Measurements

Dimensions of the feedthrough assembly shall be measured for conformance to the drawing requirements on SC-444-315-01, and University approved Seller drawings.

4.7.1.5 Contact Requirements

Insertion Force Test

steel test pin diameter:	.0370+.0001 in
test pin finish:	16 pin
number of insertions:	500
insertion depth:	.050/.075 in
insertion force:	3 lb, max

Withdrawal Force Test

steel test pin diameter:	.0355-.0001 in
test pin finish:	16 pin
number of insertions:	500
insertion depth:	.050/.075 in
withdrawal force:	1 oz, min

4.7.1.6 RGA Tests

Feedthroughs will be scanned for residual gases using a RGA Mass Spectrometer. When scanning for mass 1 to mass 100 at 150°C, peaks above mass 44 shall be less than 5×1^{-12} Torr, and the sum of all peaks above mass 44 shall be less than 1×10^{-11} Torr.

4.7.1.7 Drop Tests

The feedthrough will be dropped in any orientation from 24 inches onto a concrete floor. A vacuum leak test as described above will be performed. The mechanical, vacuum and electrical integrity of the

BPM feedthrough will be evaluated. Failures after this test will be a cause for rejection.

4.7.2 Electrical Tests

All sub-sections in section 3.4.

5.0 Documents

5.1 Submittal(s) Required Prior to Award of Contract

5.1.1 Layout Drawing

The Seller shall submit the BPM layout drawing prior to the award of contract. Drawing must include major dimensions and material call-outs.

5.2 Submittals(s) Required After Contract Date

Fourteen calendar days after the receipt of order and prior to the start of production, the Seller shall deliver the following documents for review by the University. The University will notify the Seller of its approval or disapproval within 30 calendar days.

5.2.1 Quality Program

Evidence of its quality program/system: such evidence may consist of a copy of the Seller's approved QA/QC Manual, a QA/QC plan, or a combination thereof, and shall specify the standard(s) upon which the system is based.

5.2.2 Manufacturing and Cleaning Process Plans

The Seller will submit for approval a concise explanation of all manufacturing processes, assembly procedures and cleaning processes to the University prior to manufacturing. Also, describe how material and components will be marked, identified, and tracked.

5.2.3 Inspection and Test Plan

The plan shall specify, as a minimum: (a) what is to be inspected/tested (e.g., components, subassemblies, and assemblies, (b) the inspections/tests to be performed, (c) the inspection/test methods or procedures to be used, and (d) the inspection sampling plan and frequency.

5.2.4 Detail Drawings

Prior to manufacturing, the Seller shall provide the University with a complete set of drawings showing dimensions and details of all parts internal and external. They will also submit a detail drawing of the external dimensioning and tolerancing of the feedthrough and all assembly and subassembly drawings. Drawings must be approved by the University prior to the start of fabrication. The University approval of the drawings in no way relieves the Seller from responsibility to meet all requirements of this specification.

5.2.5 Nonconformace and Corrective Action

Any departure from the requirements of this specification that the seller proposes to make shall be documented and submitted to the University for approval.

5.3 Proprietary Information

Any information of a proprietary nature shall be noted in the bid response and final Seller's documentation.

5.4 Handling and Delivery Documents

The seller shall submit a procedure for the handling, packaging and shipment of the components. University approval of this procedure is required prior to shipment. This obligation shall not relieve the Seller from delivering the BPM assemblies without damage.

6.0 Preparation for Delivery

6.1 Preservation and Packaging

When packaged, feedthroughs shall be free of moisture, oils, dirt, soils or any residues from surface preparation. Feedthroughs shall be totally enclosed and sealed in a moisture free environment. Feedthroughs will be packed with sufficient support for shipment to ensure integrity of the part. The Seller shall submit a procedure for the handling, packaging and shipment of BPM's.

The University approval of packaging, handling and shipping procedure is required prior to making the first shipment.

6.2 Marking for Shipment

Exterior of shipping containers shall be adequately and properly marked for identification. All containers shall include the following minimum exterior marking:

a. Addressee
b. Shipper
c. The University subcontract or purchase order number
d. Special markings, warnings or tags in accordance with ICC regulations.

6.3 Shipping Address

Stanford Linear Accelerator Center
2575 Sand Hill Road
Menlo Park, CA 94025
Attention: Leo Giannini