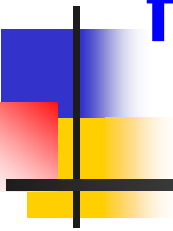


High RF Power Couplers & SQUID NDT for the International Linear Collider



Quan-Sheng Shu

AMAC International, Inc.

Snowmass, CO, USA, August 14-27, 2005

**AMAC's R&D Work on High RF Power Coupler and SQUID NDT
includes contributions by:**

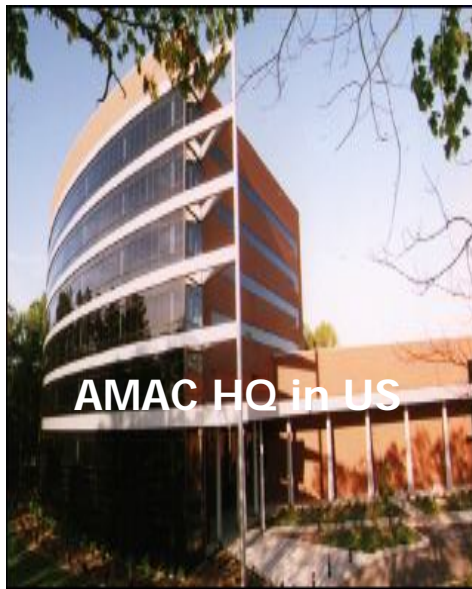
**Q. S. Shu, J. T. Susta, G. Cheng (AMAC), T. Treado, S. Einarson (CPI) ,
W. D. Moeller, D. Proch, D. Kostin (DESY), V. Yarba, N. Solyak,
T. Khabiboulline, P. Bauer (Fermilab), T. Garvey (Orsay), P. Kneisel,
G. Myneni, M. Stirbet (Jlab), I. Campisi (SNS), and T. Grimm (MSU)**



Contents

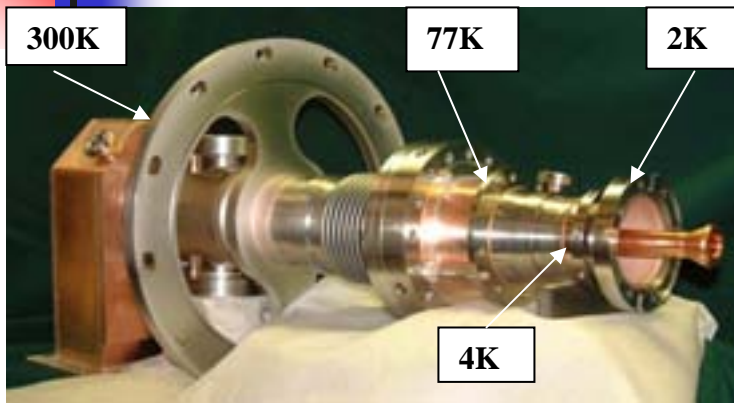
- **AMAC International Inc.**
- **Track Records on SRF Technology**
- **SQUID-based NDT of Nb for ILC Cavities**
- **AMAC Proposals for ILC Power Couplers**

AMAC International Inc. in Newport News, Virginia is a high tech company operating at the cutting edge of technology.



- Based on AMAC's excellent SRF achievements, AMAC has been awarded more than \$2,000,000 of innovative research grants from the US Department of Energy
- Due to successful development in Magnetic Levitation and Cryogenics in space, the US National Aeronautics & Space Administration has supported AMAC's research activities with \$800,000.
- AMAC has collaboration and research agreements with DESY (Germany), Fermilab, ORSAY (France), Jefferson Lab, Michigan State University, Oak Ridge National Lab and the Chinese Academy of Sciences.
- Commercialization— AMAC in partnership with CPI, MTM, and ATZ has delivered high tech products to many Leading projects: FEL, SNS, RIA, TESLA and NASA Space Flight Program.
- In 2005, AMAC has been awarded by US DOE three new SBIR projects to encourage our continual R&D on SRF technologies.

Track Records on SRF Technology

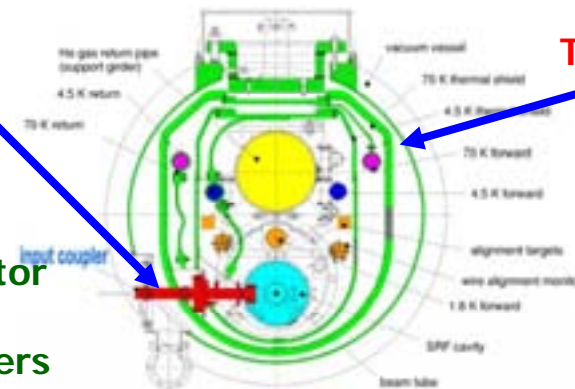


New TESLA High RF Power Couplers

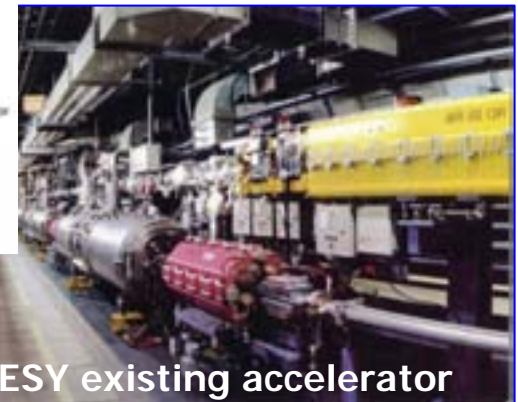
- TESLA is a 15 countries international Project
- Energy 1-TeV:
500-GeV e+e- collider
- Two 10km-active-length-accelerator
- 20,000 superconducting cavities
- 10,000 high RF power input couplers
- Superfluid Liquid He inventory: 95,000kg
- The first step of TESLA: TESLA TTF at DESY
200 m long is in operation with FEL aspects

AMAC has signed a joint agreement in 2003 with DESY to develop a novel, reliable, low cost high power input coupler for the international TESLA project.

Two New TESLA High RF Power Couplers have been designed by AMAC and fabricated by CPI, and are being tested at DESY



TESLA Cryomodule

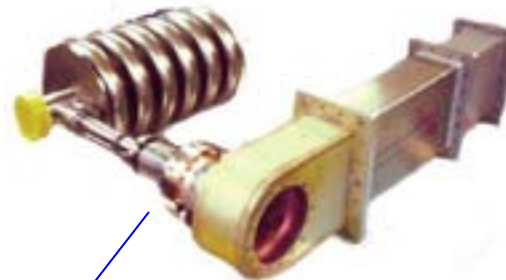
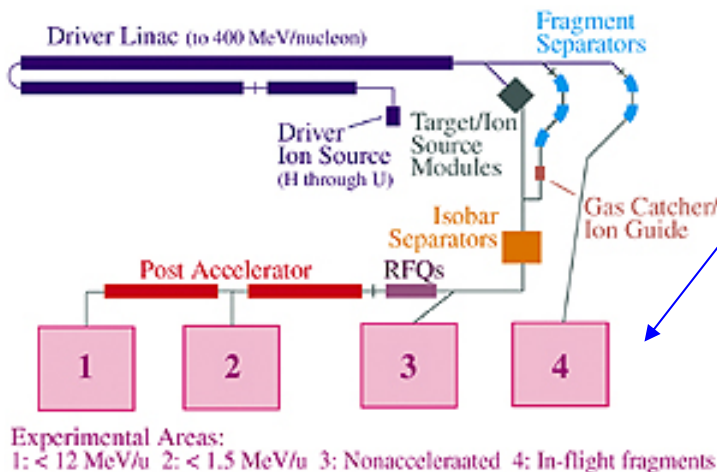


DESY existing accelerator

Track Records on SRF Technology

The Rare Isotope Accelerator (RIA) will be the world's most powerful research facility dedicated to producing and exploring new rare isotopes that are not found naturally on Earth

**AMAC's Contribution (RF Power Coupler)
For RIA, at Michigan State University**



To be used at RIA

Tested at Jefferson Lab

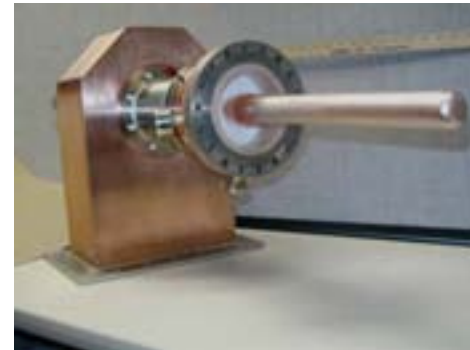


Track Records on SRF Technology

➤ The Spallation Neutron Source (SNS) is an accelerator-based neutron source being built in Oak Ridge.

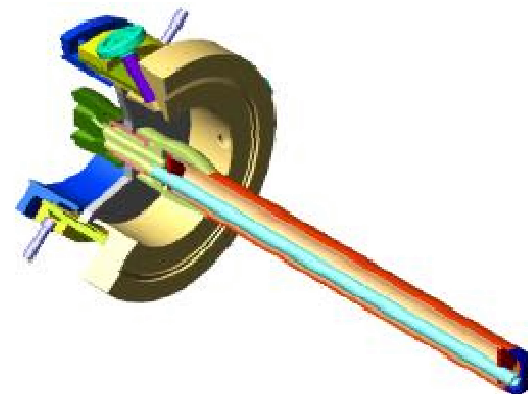
➤ AMAC, in partnership with CPI, produced three prototype RF power couplers (2MW pulse, max. CW RF Power = 53kW CW) for the SNS project. (2002)

➤ The SNS will provide the most intense pulsed neutron beams in the world for scientific research and industrial development.



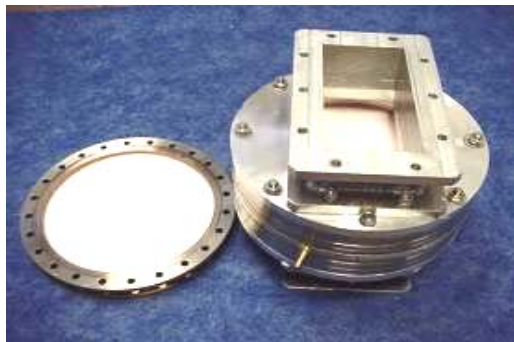
AMAC Design SNS High RF Power Coupler wit Compression Ring.

MAX. CW RF Power = 200 kW



Track Records on SRF Technology

- The innovative design features (compression ring and internal cooling) of the AMAC window were fully tested and verified to a 2MW peak RF power.
- The innovations of the new window couplers can be used in many RF tube window designs and fabrications, and in world-wide accelerator projects, such as SNS, Jefferson Lab upgrade, RIA, TESLA, and ILC.



**Waveguide Window
With compression ring**



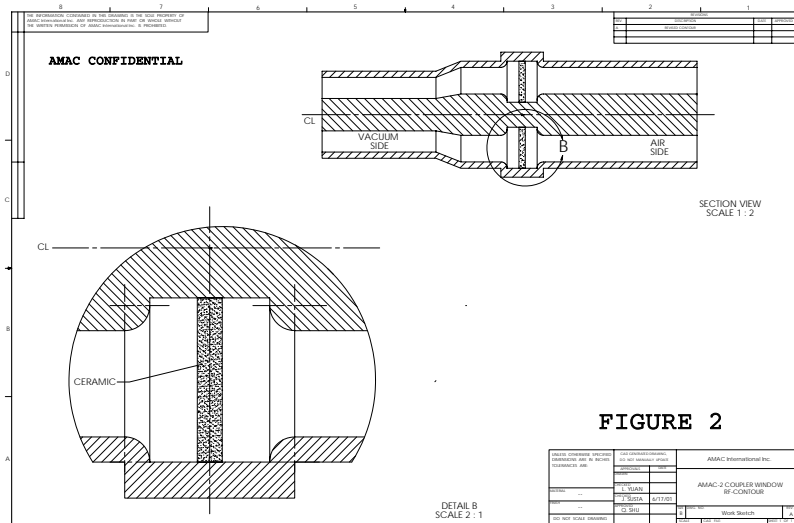
Couplers with compression ring

Track Records on SRF Technology

RF Surface Shape Consideration

AMAC-II Chokeless Design

- An innovative RF surface design without choke has been successfully developed by AMAC, fabricated by CPI, and tested at Jefferson Lab.
- Designed for easier machining & cleaning
- Better vacuum
- Less electronic multipacting
- With insignificant increase of local H/E fields



Electron Multipacting at the AMAC I design – with chokes at the ceramic window:

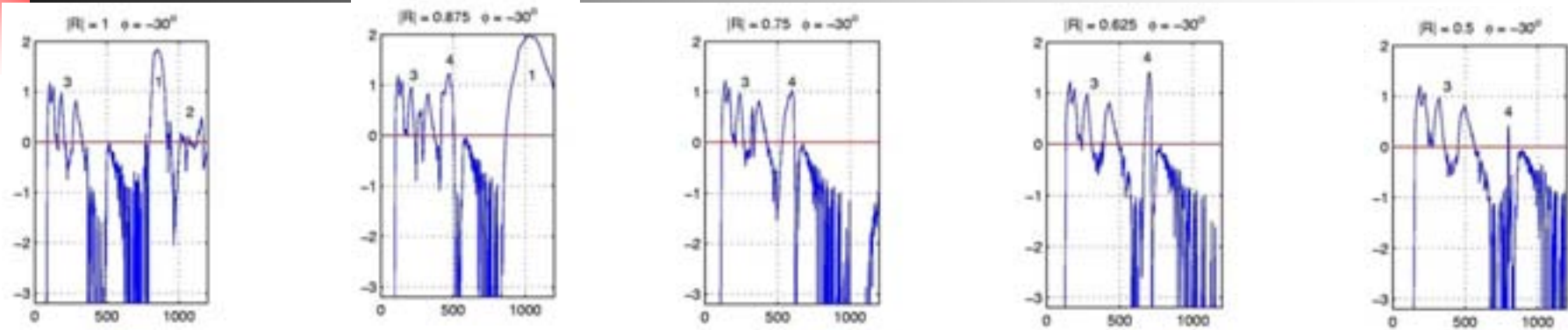


Fig. 1. Relative Enhanced Counter Function

(53 kW average, 1.2 MW peak power)

- **The secondary electron emission values for TiN were used for the ceramic window surface.** These calculations are used to validate the coupler geometry in the design stage. **The maximum RF power is 1.2 MW**
- The description and results of the calculations are shown in Figs: $R=1$ corresponds to full reflection (**standing wave**) with an electric minimum at the center of the window, and $R=0$ corresponds to a **traveling wave** condition. The SNS window is installed at a phase position of -30 degrees.

Electron Multipacting at the AMAC II design – without chokes at the ceramic window: **Multipacting level -----without chokes is much better than with chokes**

(Plots have same definition & scale as for with chokes)

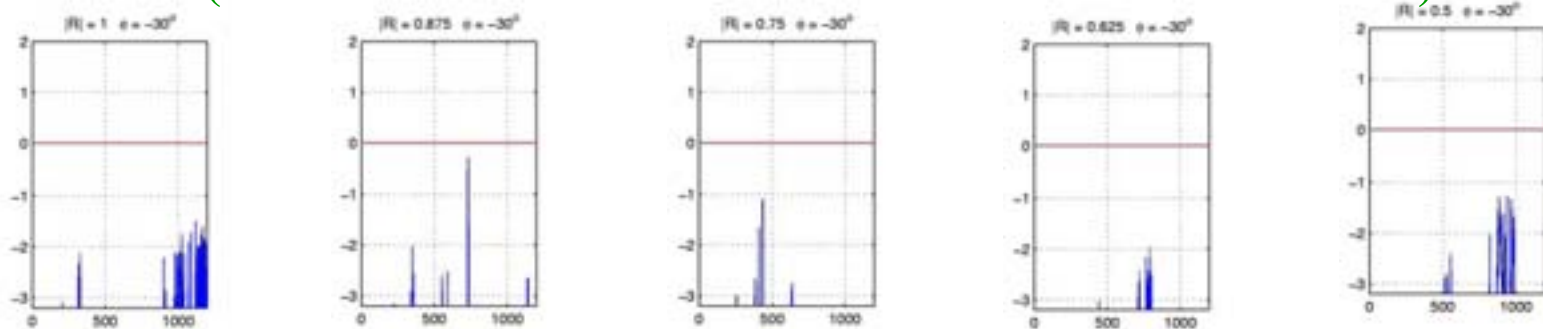


Fig. 1. Relative Enhanced Counter Function

(53 kW average, 1.2 MW peak power)

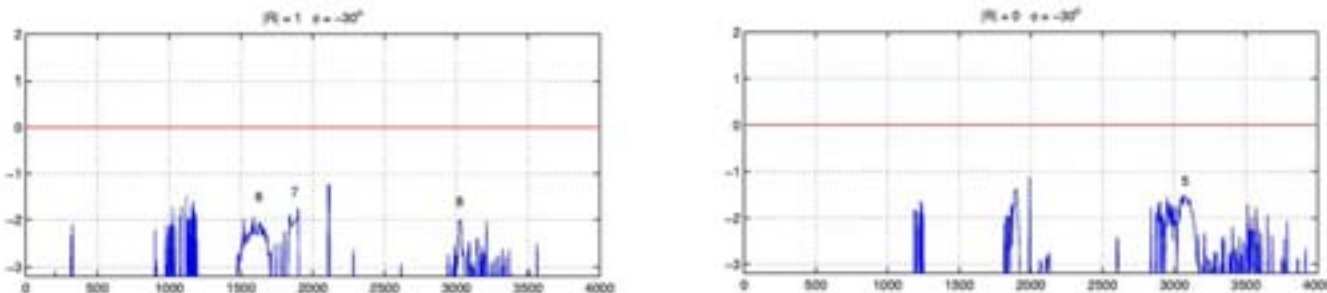


Fig.2. Relative Enhanced Counter Function

(348 kW average, 4 MW peak power)

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Ongoing SBIR Projects on SRF R&D

➤ ILC 1.3GHz RF Couplers with Double Windows Design and Self-kept Vacuum”— DOE 2005 SBIR Phase I

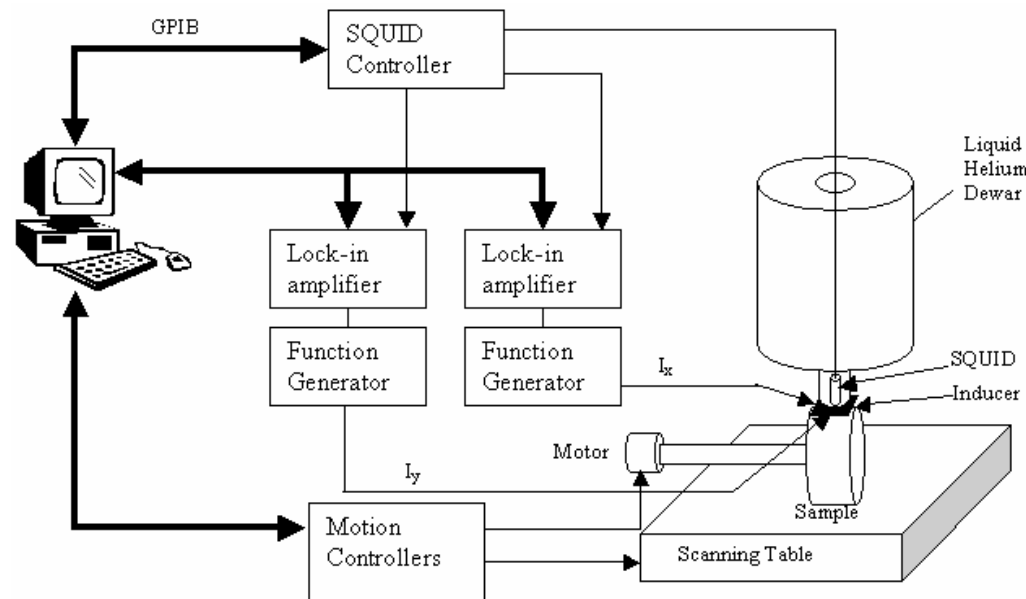
The proposed innovative **double-window** RF power input coupler technology could be applied to many DOE accelerator projects such as RIA, SNS, Muon Collider & Jefferson Lab upgrade. The fabrication technologies developed here can also be widely used in RF power, communication and high vacuum industries.

➤ Innovative Modular, Multiple Power Levels, 325 MHz Spokes Cavities Power Couplers ”— DOE 2005 SBIR Phase I

The design of high reliability RF power couplers with modular components for three different power levels will maximize the number of common parts and fabrication fixtures to reduce significantly the fabrication costs for the 110 couplers required for the Fermilab Proton Driver. The technology will be also used in many DOE accelerator projects and industrial applications.

Ongoing SBIR Projects on SRF R&D

➤ SQUID-based Nondestructive Testing Equipment of Dished Niobium Sheets for SRF Cavities — DOE 2005 SBIR Phase I



The proposed innovative SQUID based three dimension high sensitivity testing equipment is the first time to enable the inspection & qualification of complex, curved Nb sheets and superconducting cavity.

AMAC's Proposals for ILC Coupler

- New couplers designs will require some flexibility in the cryostat design, the installation procedure, and the overall assembly philosophy. If the TESLA cryostat design and assembly procedure is adopted as is, then there is little or no possibility of developing a new configuration because of the special constraints (available space and assembly sequence).
- SBIR's are funded to investigate innovative ideas, and we will investigate some power coupler alternatives to the TESLA design. These ideas are being developed now by AMAC and Fermilab under a SBIR Phase-I DOE grant.
- Four coupler design versions will be investigated for RF and Multipacting characteristics, and manufacturability.

AMAC's Proposals for ILC Coupler

Proposal 1, Separated Cold and Warm Windows:

The design drawing will be presented
at the ILC G5 working group.

AMAC's Proposals for ILC Coupler

Proposal 1, Separated Cold and Warm Windows:

Simplified TESLA design with pumping of the space between the windows thru the inner conductor. The space between the windows can be filled with dry Nitrogen, and would be pumped only in the case of a leak in the cold window. DESY will perform tests on the coupler developed by AMAC for the TESLA superstructure, to verify the voltage holding capability of the Nitrogen gas fill.

Advantages:

- a. The dry Nitrogen fill eliminates multipacting problems between the windows
- b. Cost reduction because it essentially eliminates the cost of the pumping system, because it would be only necessary to pump locally only if the cold window develops a leak
- c. Cost reduction because of simplified mechanical design without large pumping ports and special cryostat flanges.

Disadvantage: Reduced pumping speed between windows

AMAC's Proposals for ILC Coupler

Proposal 2a, Single-Module Cold and Warm Window:

The design drawing will be presented
at the ILC G5 working group.

AMAC's Proposals for ILC Coupler

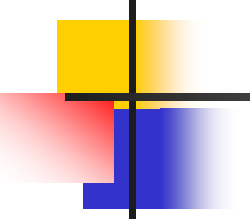
Proposal 2a, Single-Module Cold and Warm Window (with active pumping between windows)

Advantages:

- a. **Lower cost**
- b. A developed clean assembly tool would permit the "anytime" coupler replacement without cavity removal (the present TESLA assembly requires the cavity removal to replace the cold window)

Disadvantages:

- a. Requires development of clean assembly tools
- b. Lower pumping speed between windows



Proposal 2b, Single-Module Cold and Warm Window (with self-kept sealed vacuum between windows)

Advantages:

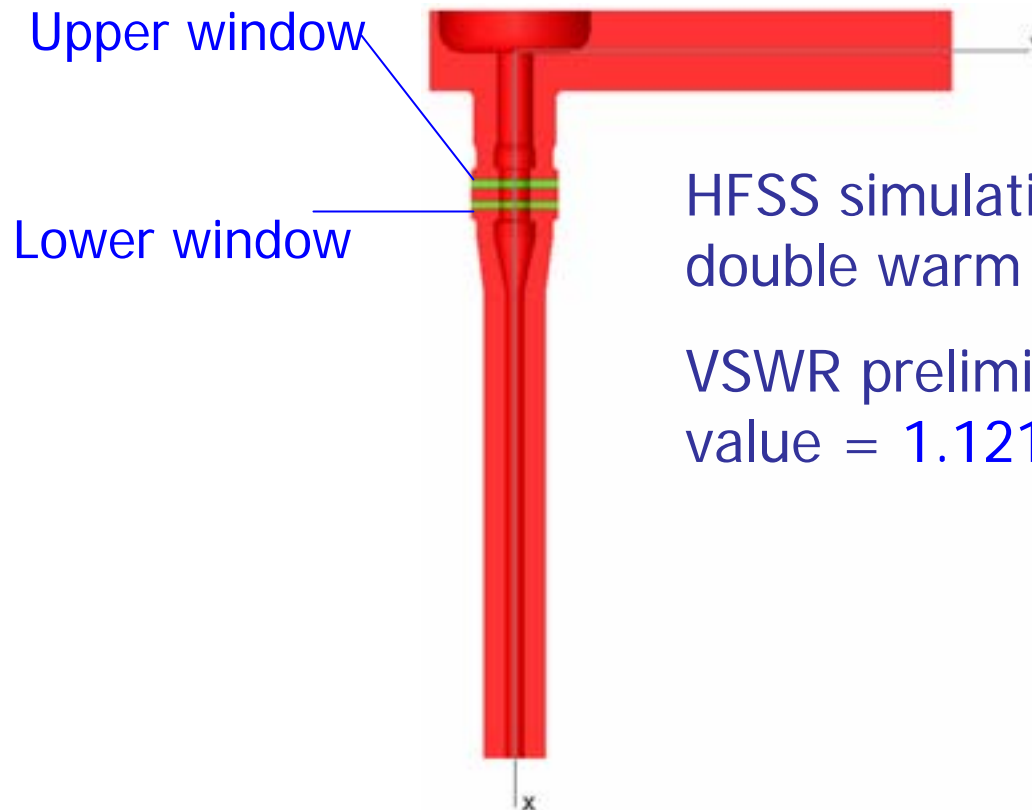
- a. Lower cost
- b. A developed clean assembly tool would permit the “anytime” coupler replacement without cavity removal (the present TESLA assembly requires the cavity removal to replace the cold window)
- b. No active pumping system is required

Disadvantages:

- a. Requires development of clean assembly tools
- b. Lower pumping speed between windows

AMAC's Proposals for ILC Coupler

Proposal 3, Single-Module, Two Warm Windows with self-kept sealed vacuum, active pumping, or Dry Nitrogen fill



HFSS simulation model for double warm window proposal.

VSWR preliminary optimized value = 1.121

AMAC's Proposals for ILC Coupler

Proposal 3, Single-Module, Two Warm Windows with self-kept sealed vacuum, active pumping, or Dry Nitrogen fill

- Advantages:**
- a. Lower cost
 - b. A developed clean assembly tool would permit the “anytime” coupler replacement without cavity removal (the present TESLA assembly requires the cavity removal to replace the cold window)
 - b. No active pumping system is required
 - a. Inner Window is located far away from the cavity
 - b. No condensation of gases on windows

Disadvantages:

- a. Requires development of clean assembly tools
- b. Higher radiation heat load from antenna to cavity



Thanks for your time!

AMAC welcomes research opportunities in the direction of improving present SRF accelerator technology.

AMAC and its partners look forward to making contributions to the ILC project.