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Ka-BAND TEST FACILITY AT YALE FOR AARD TOWARDS DEVELOPMENT OF HIGH-GRADIENT ACCELERATOR STRUCTURES*

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MOTIVATION

1. Many recognize the need for long-term AARD to find a pathway towards achievement of high gradients (HG) in warm structures, so as to enable the future design of a multi-TeV e^--e^+ collider.* (*See recent Marx sub-panel report to HEPAP.*)

2. A vibrant US program that is independent of, but coordinated with, the CLIC study at CERN is essential for maintenance of a viable, influential, US presence internationally in AARD.

3. Facilities in the US for HG R&D experimental testing are limited, only existing at SLAC and NRL (11.4 GHz), and at MIT (17.1 GHz).

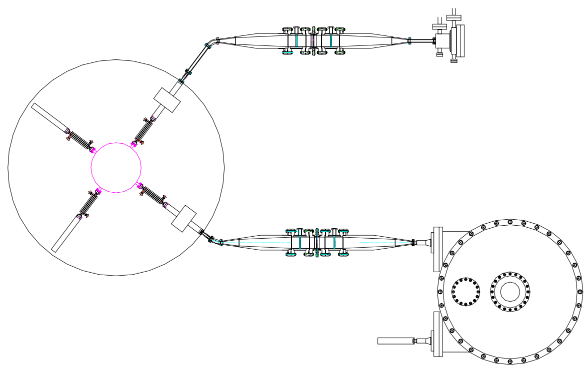
4. The 34.3 GHz magnicon is operating at Yale with sufficient power for a number of AARD experiments; high-power components have been developed to transport power to up to four independent test cells.

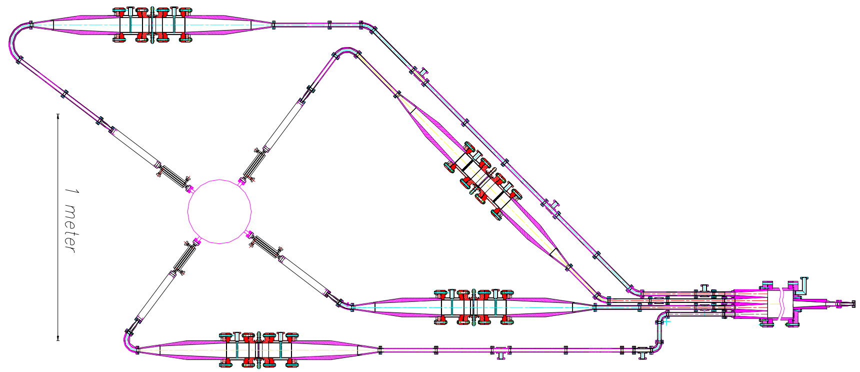
5. It seems opportune to now begin organization of a “user's test facility” at Yale for HG R&D, and DoE has been engaged for support in this endeavor.

** “HG” is taken to refer to an acceleration gradient in the range of 150 MeV/m.*

STEPS TOWARDS ESTABLISHING THE TEST FACILITY - I

1. Configure the facility (10/06 onwards).
   a. Fixed LHe transfer system.
   b. Elevated platform to open the floor space, and to increase experimental area.
   c. Four transmission lines and output windows, bakeout and re-conditioning of tube.
   d. Replace cryomagnet (to reduce LHe consumption). Delivery expected in 12/06.
   e. Install two experiments (pulsed heating, passive QO pulse compressor).
   f. Replace line-type with DTI Marx-bank modulator (500 kV, 120 Hz, 1.6 μs). In ~7/07.
   g. Install and test the four-way power combiner.





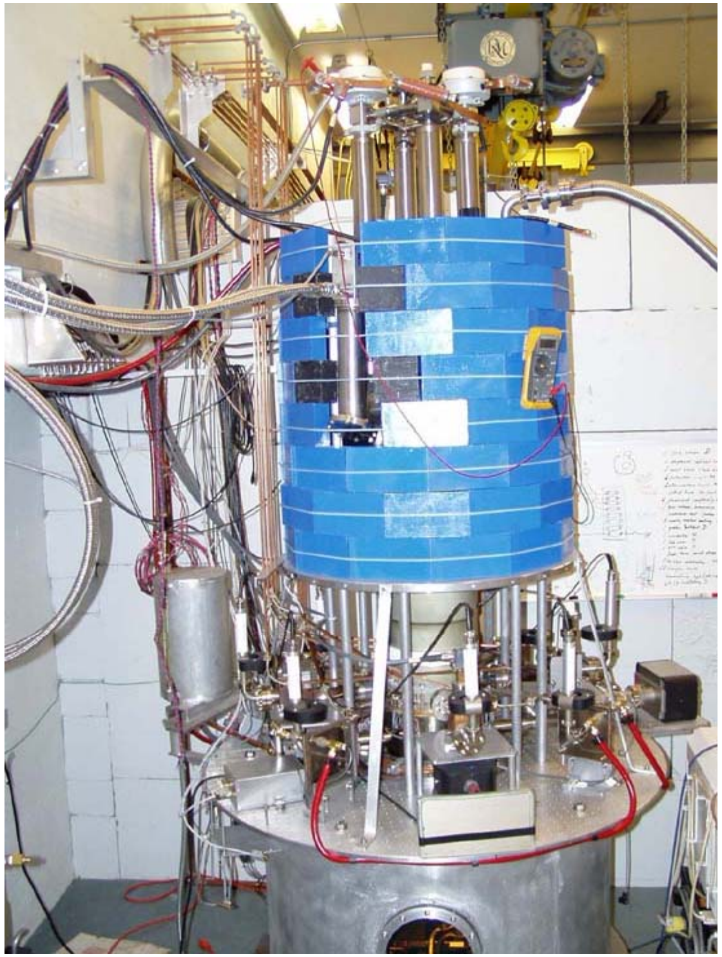
STEPS TOWARDS ESTABLISHING THE TEST FACILITY – II

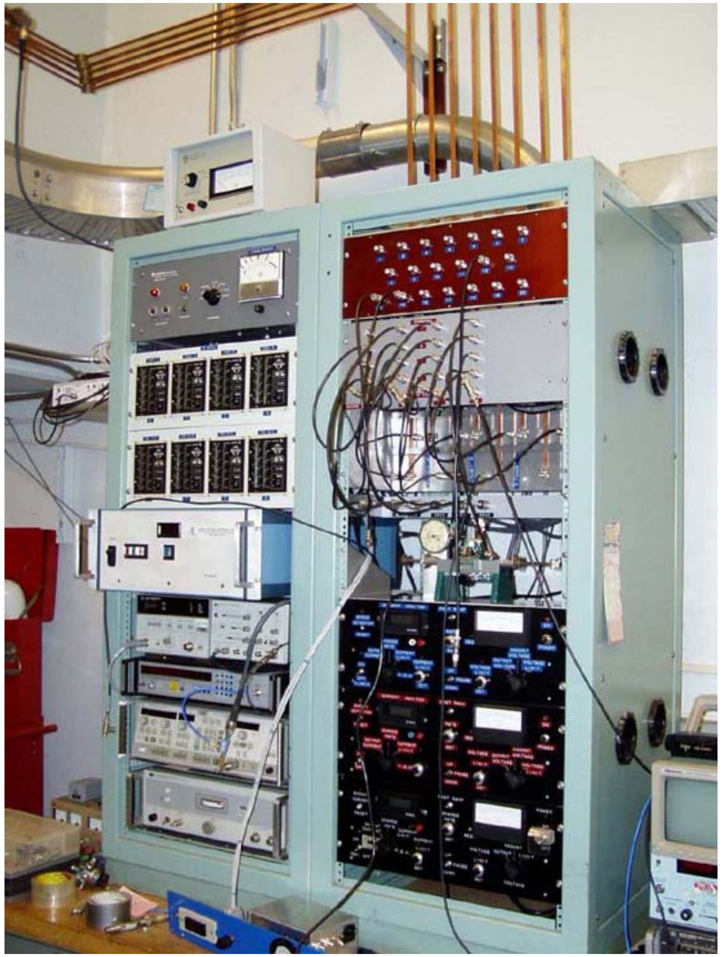
2. Operate the facility (01/07 onwards).
   a. Run first two experiments (pulsed heating, passive QO pulse compressor).
   b. Prepare follow-on experiments (RF breakdown, active QO compressor, …..)
   c. Schedule outside users' experiments (SLAC, CERN, ANL, Euclid, IAP…..)

3. Maintain the facility (01/07 onwards).
   a. Automation for magnicon operation.
   b. Add data collection and archiving instrumentation for user's experiments.
   c. Routine maintainance.

4. Governance. *Need is recognized for an eventual protocol to govern approval of proposed experiments, scheduling, safety and access oversight of visiting personnel, etc….. To early yet to anticipate details—except to aim for institution of some governance before the end of the third year.*

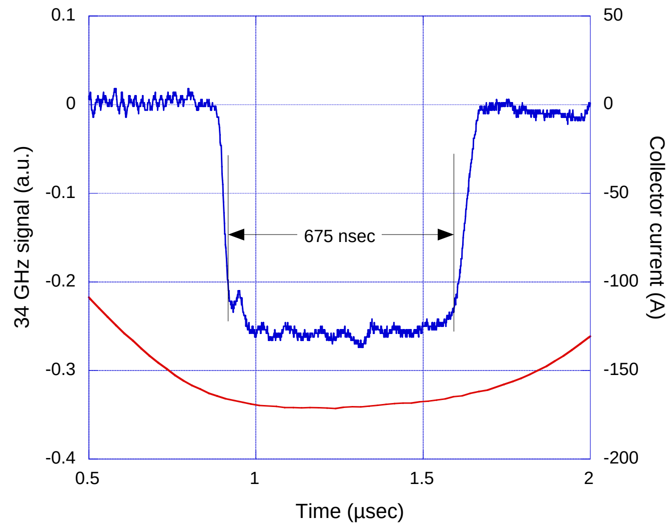
Yale/Omega-P 34.3 GHz magnicon





Yale/Omega-P 34.3 GHz magnicon

output frequency	34.3 GHz
output power	31 MW / 26 MW
pulse duration	150 ns / 700 ns
pulse repetition rate	up to 6 Hz
RF drive frequency	11.431 GHz
RF drive power	~45 W
gain	~54 dB
beam voltage	up to 480 kV
beam current	up to 206 A
beam power	up to 99 MW



Ka-band transmission line components*

f = 34.272 GHz / 10-200 MW / 0.1-1μs

- **High-power loads in WR-28 and circular waveguide**
- **Miter bends for WR-28 and circular waveguides**
- **Power combiner**
- **Barrier windows**
- **Mode converters**
- **Bi-directional coupler in WR-28 waveguide**
- **Waveguide up-tapers**
- **Resonant ring**

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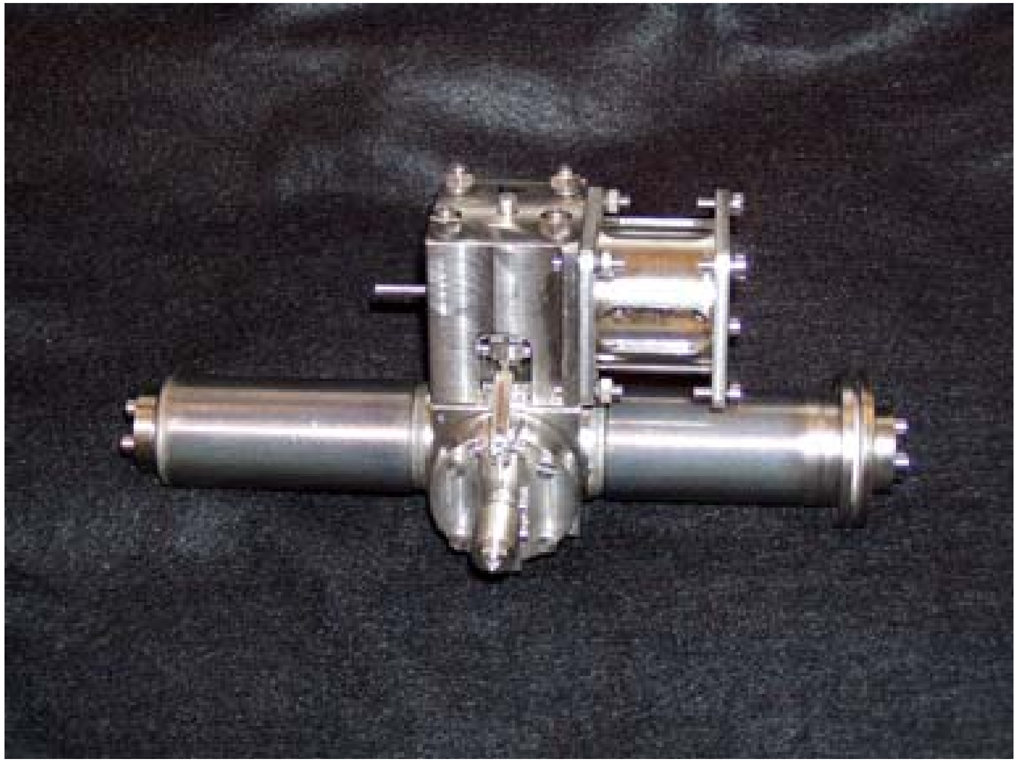
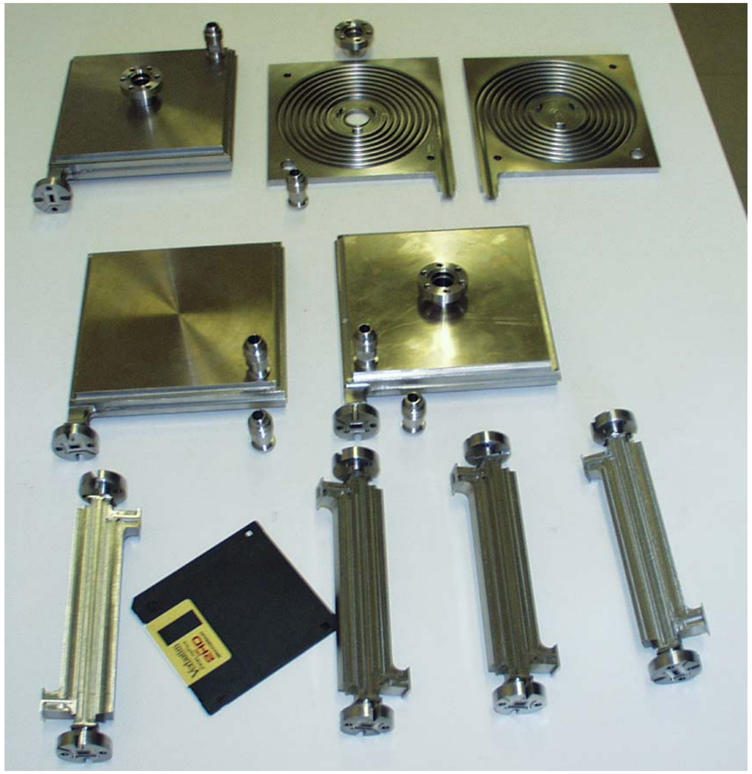
High-power 34-GHz components

WR-28 phase shifter, with
remotely driven stepper motor

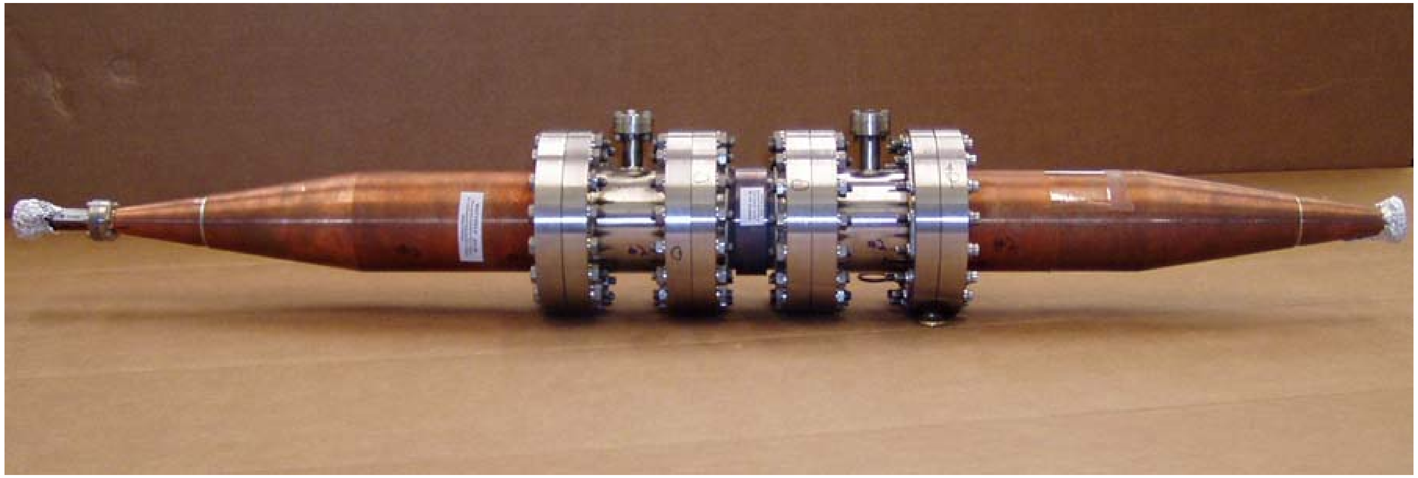
vacuum loads (10 MW)
dual directional couplers



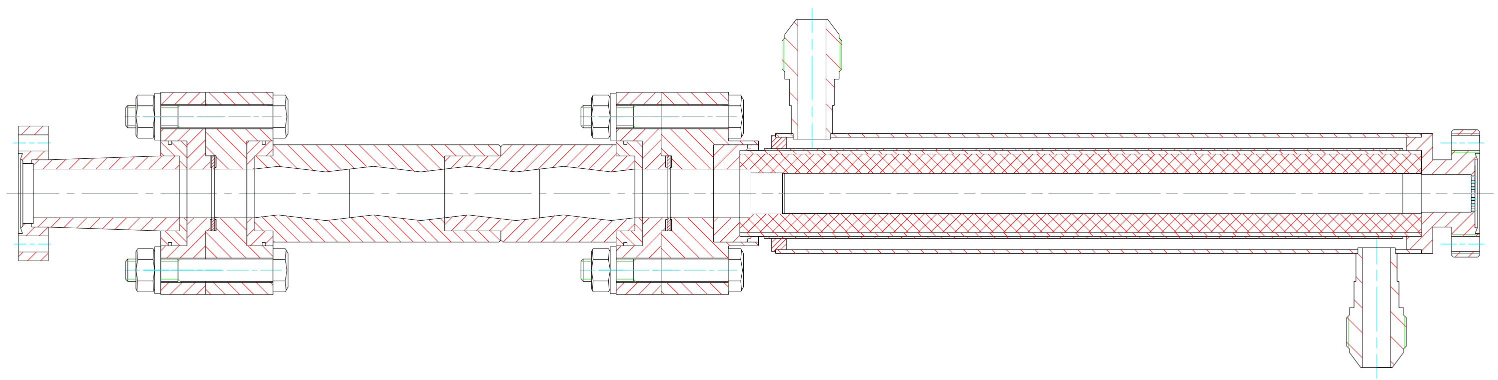


High-power 34-GHz components

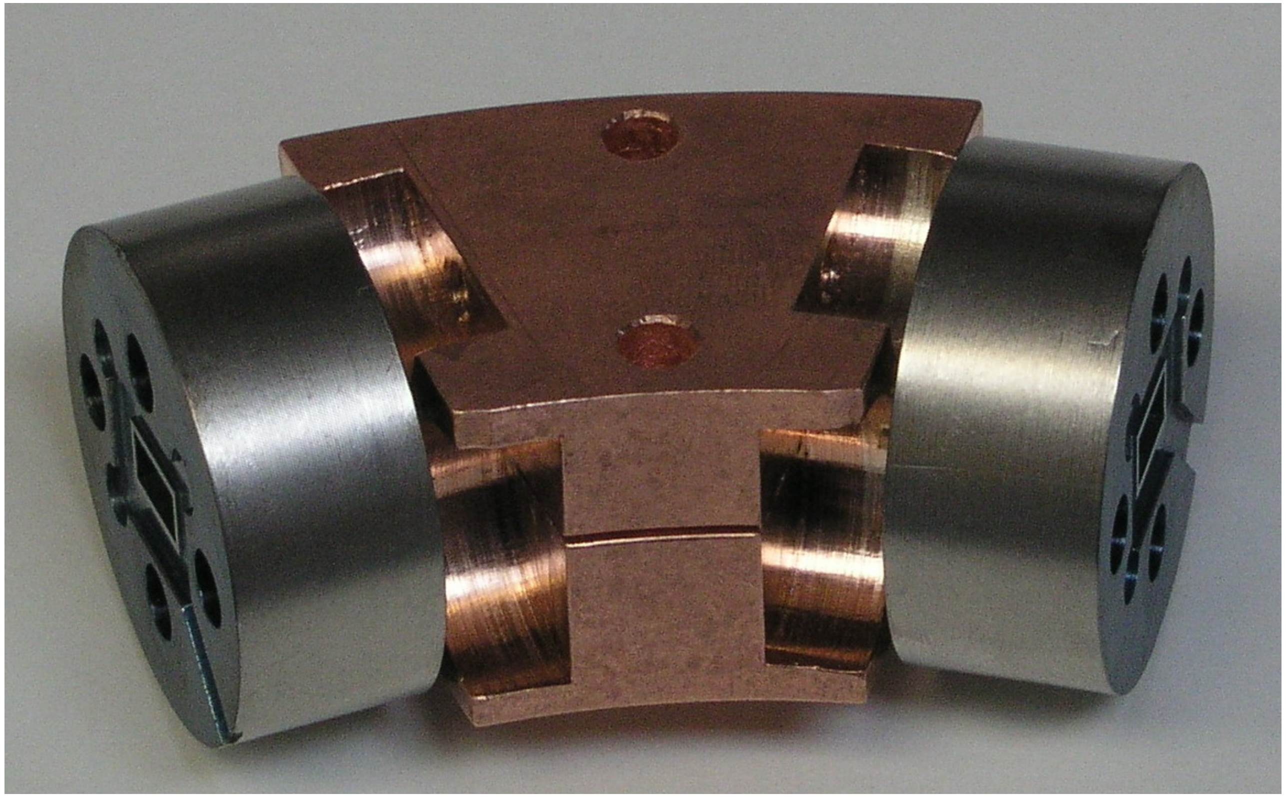
10-MW window assembly, and
four-way power combiner



High-power load for circular waveguide



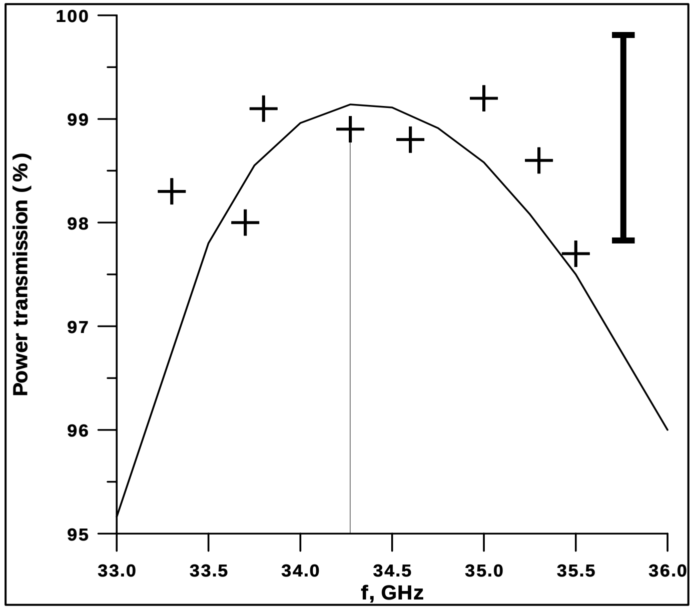
H-bend for WR-28



Miter bend for circular waveguide (∅13 mm)

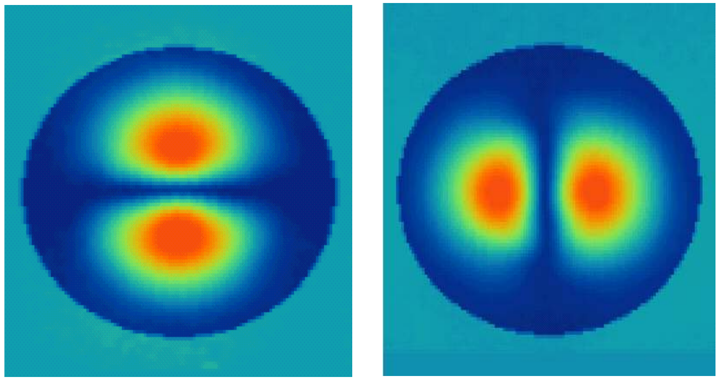
Mitre bend for TE_{01} mode - low power test

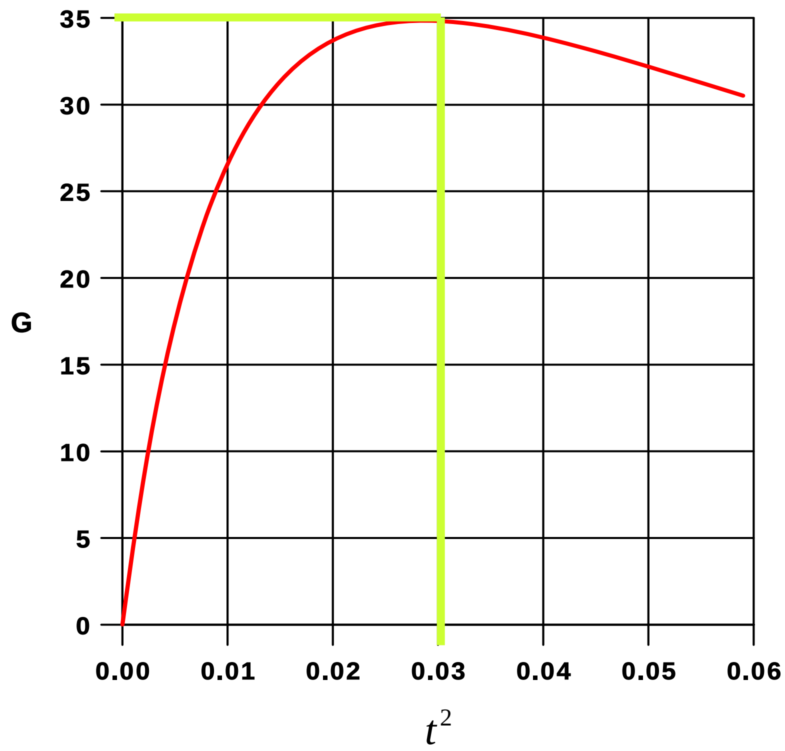
The setup for tests included a microwave oscillator (BWO, 26 - 38 GHz), directional couplers, Marie mode transducer, producing TE01 mode in 11.4 mm diameter waveguide, TE01 up-taper to 63.5 mm waveguide diameter and the miter bend



Miter bend efficiency

Measured field amplitude patterns (E_x^2, E_y^2) at the position of flat mirror in the miter bend

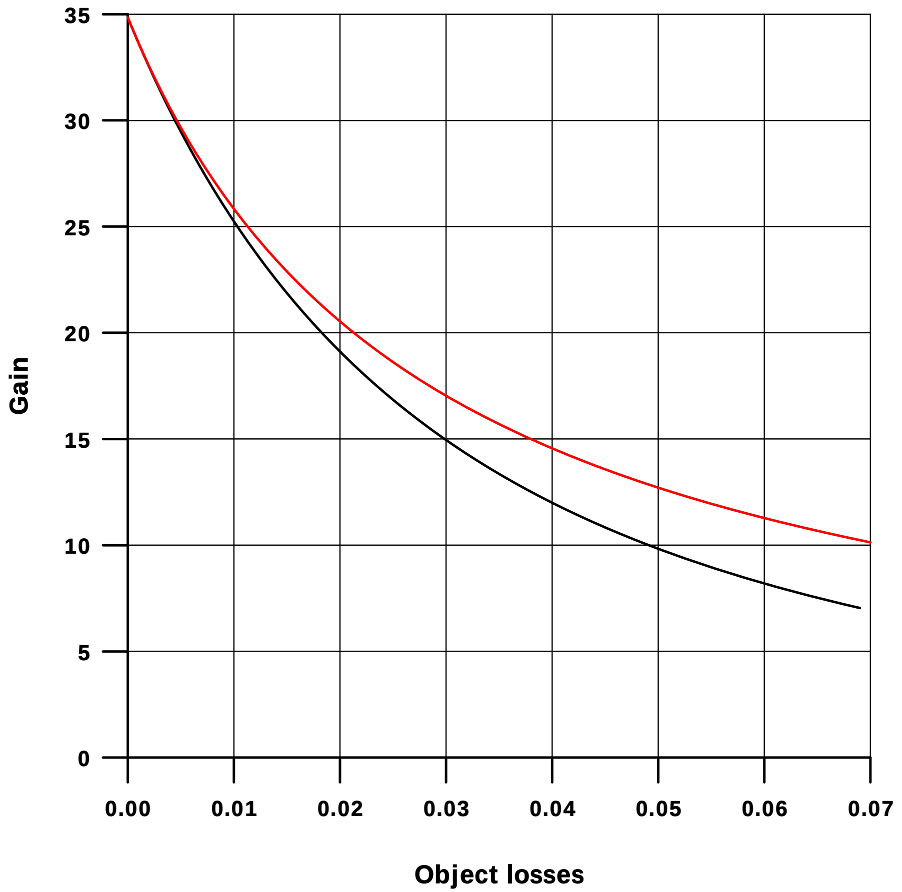




Coupling hole plate:
Thickness=0.55mm,
hole period = 4.93mm,
hole diameter=3.0mm
Transmission coefficient ~ 3%

Power gain inside the ring G versus coupling coefficient t^2

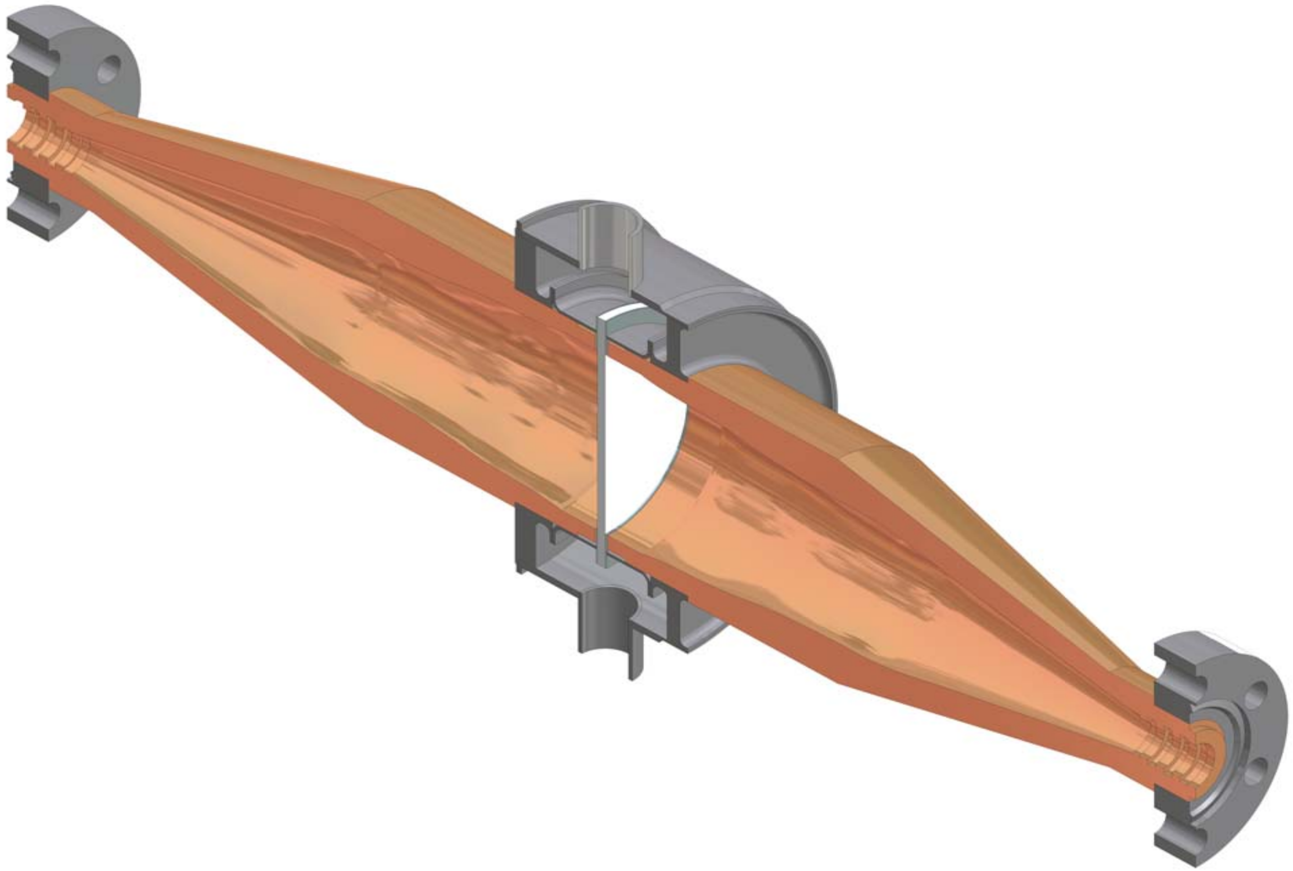
Ohmic losses ~0,5%
Losses in 4 meter bends ~3%



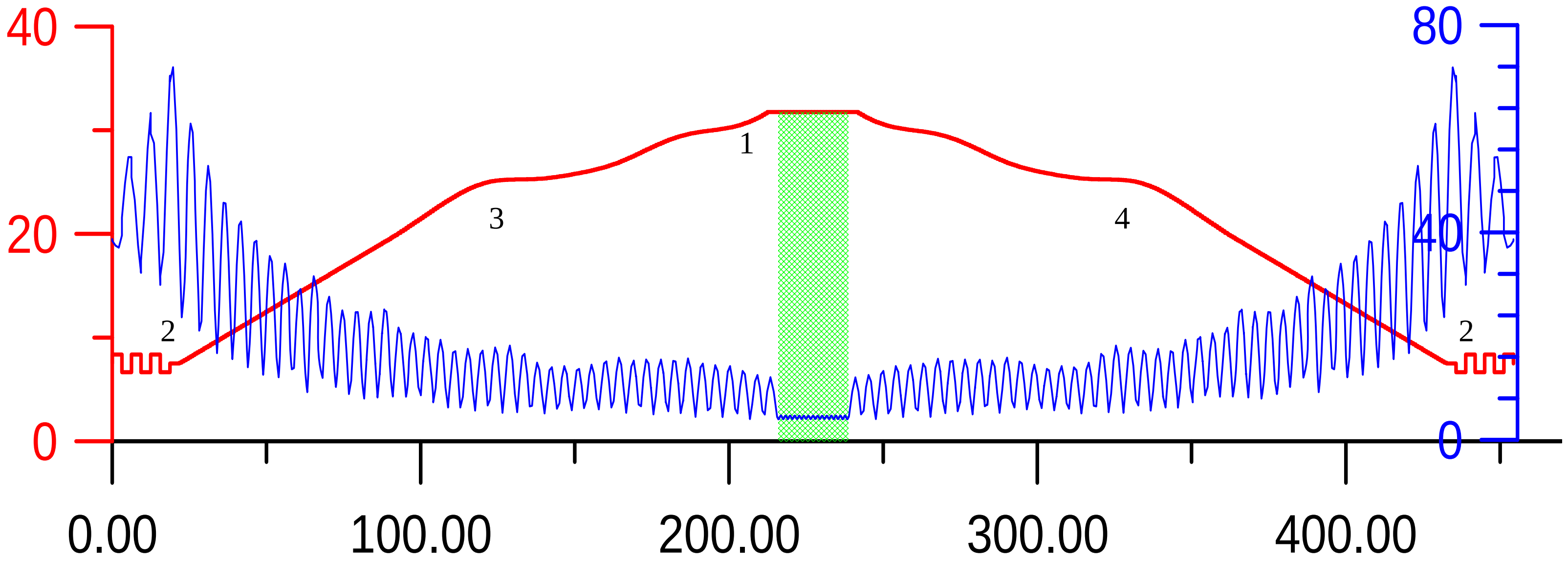
Estimated round trip losses in the ring are approximately 3% (!) including Ohmic losses and losses due to scattering of the operating mode TE01 into other modes.

Of course, if the component under test that is inserted into the ring has losses of its own, this will reduce the effective power gain. Figure shows how the gain drops with added loss, for a ring with 35:1 intrinsic gain. Two curves are shown, the lower curve for the case of no change in the coupling; the higher curve for change in coupling to maximize the gain at each point. For the lower curve, it is seen that insertion of a component with loss of 3% would reduce the gain to 15:1.

If 30 MW power from the magnicon were available (making allowance for transmission losses), this would amount to an effective power level of 450 MW, more than twice that required for a source to test CLIC structures and components, for example.



Configuration of the proposed barrier window. Shown are mode-mixing up- and down-tapers to the 63.5 mm diameter alumina window from 15-mm diameter TE01 mode circular waveguide, grooved matching elements at entry and exit to the tapers, and a rigid supporting plenum that provides pump-out access to both sides of the window through holes not shown in the drawing.



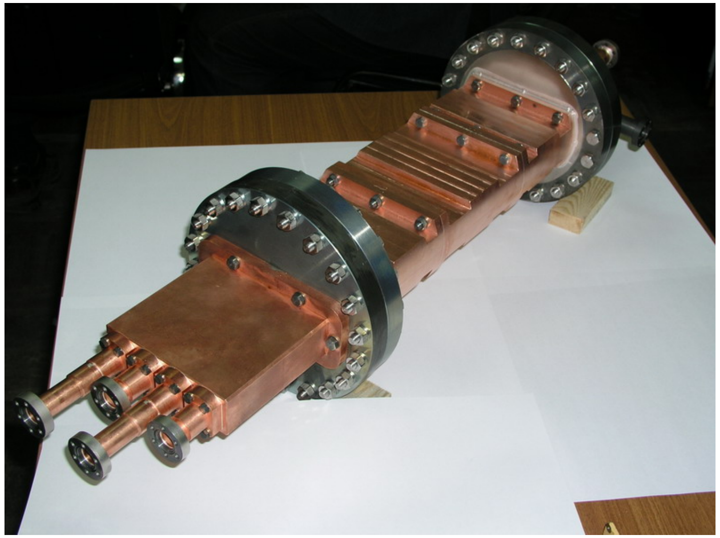
Calculated profiles (in red) of the window up- and down-tapers (3,4), and end matching reflectors (2). Alumina disk (green) is brazed to copper cuffs (1). Waveguide radius and length (in mm) are shown on the left and bottom axis.

Oscillating blue curve corresponds to the maximum electric field along the waveguide for a transmitted power of 200 MW. Right axis shows electric field strength in kV/mm, equal to 4.2 kV/mm at the dielectric surface

Waveguide sections

Mode converters

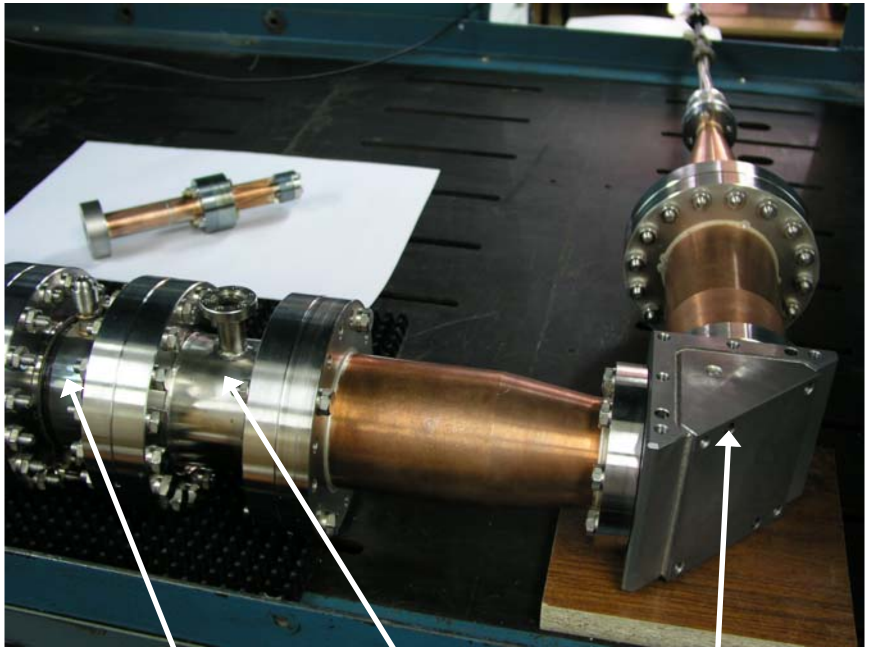
Low-reflection bends.



4:1 power combiner

Ka-band component assembly, including barrier window, miter bend, pump-out sections, tapers, and mode converters. Transmission efficiency of the assembly is 95%.

Components for high-power evacuated line



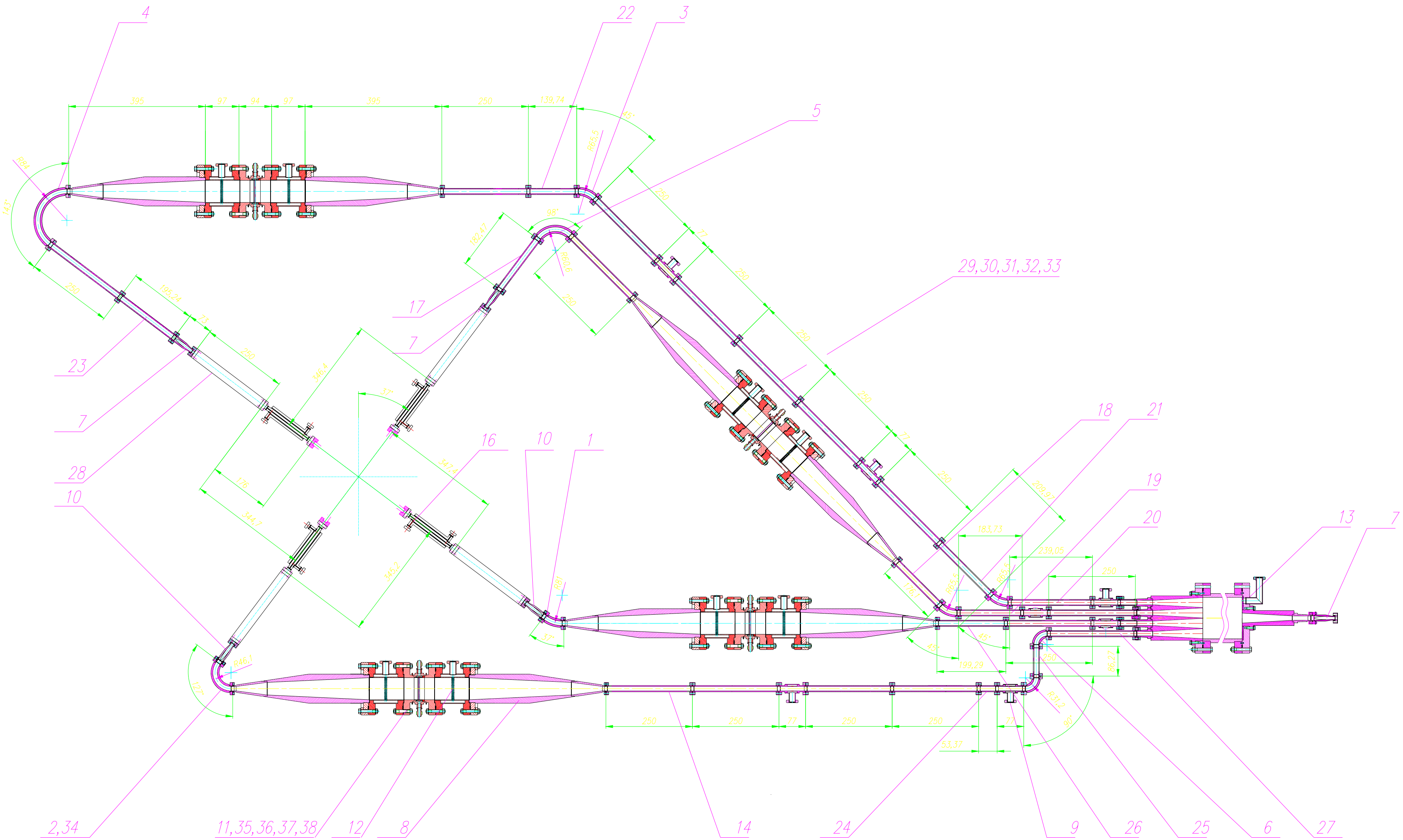
$TE_{10}^{\square}$ - $TE_{11}^{\bigcirc}$ - $TE_{01}^{\bigcirc}$ converter

Window

Pumping port

Miter bend

Scheme of transmission line



Summary

- Yale/Omega-P 34-GHz magnicon is providing sufficient power for first AARD experiments aimed towards achievement of high acceleration gradients in warm structures.
- Steps towards establishing a test facility at Yale will be underway, beginning in October 2006.
- A full menagerie of necessary developed-to-order high-power components is at hand.
- First experiments await installation, scheduled to begin in Spring 2007.
- Expressions of interest and moral support are welcome.