quarter wave resonators for beta~1 Accelerators

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Why the QWR?

- Most compact structure.
- Extremely high mechanical stability.
- No Same Order Mode (SOM).
- The first HOM is a factor of 2 to 3 in frequency above the fundamental crabbing mode, very easy to damp.
- Simple fabrication, coupling and tuning.
\[ Z_0 = \frac{\eta}{2\pi} \ln \frac{b}{a} \]

\[ \eta = 377\Omega \]

\[ R_{sh}/Q = \frac{4Z_0}{\pi} \]

\[ \Gamma = QR_s = \frac{2\pi \eta}{\lambda} \frac{\ln(b/a)}{a^{-1} + b^{-1}} \]

\[ H_p = \frac{1}{\eta a \ln \frac{b}{a}} \]

\[ R_t = \frac{4\pi a^2 Z_0}{g^2} \]

\[ E_p \geq \frac{V}{a \cdot \ln(b/a)} \]
SRF Quarter Wave Resonators are well known and are quite compact.

The first superconducting Quarter Wave Resonator, ca. 1981. The frequency is 300 MHz.
SUPPRESSION OF MULTIPACTING

A HOM damper with an integral high-pass filter for QWR

Q. Wu and I. Ben-Zvi, Optimization of Higher Order Mode Dampers in the 56 MHz SRF Cavity for RHIC, Proceeding of IPAC’10, Kyoto, Japan
Crab Cavities

- Big issue: Damping of LOM, SOM, HOM made simple.
- Big Issue: Size.

KEKB Crab cavity at 500 MHz
Initial LHC QWR crab cavity design

Rama Calaga

- 400 MHz
- Very easy fit into LHC
- Nearest other mode is well separated at 675 MHz
- $V_t \sim 2.5 \text{ MV} \ @ 110 \text{ mT}$ and 48 MV/m surface fields, $R_t/Q$ of 132 $\Omega$
eRHIC crab cavity initial design
Qiong Wu (THPO007)

- 181 MHz (and harmonics)
- No acceleration

QWR crab cavity for RHIC Units MWS
Crab mode frequency MHz 181
Nearest other mode MHz 251
Length (along beam line) cm 75.2
Width (long/short parts) cm 38.1/25.1
Deflecting voltage* MV 6.1
Peak surface electric field* MV/m 39
Stored energy* Joules 100
Rt/Q (Engineering def.) Ohms 291
Accelerating voltage* kV <1

*) At peak surface magnetic field of 100 mT
RHIC 56 MHz Storage Cavity

- Heavily damped HOM
- Variable fundamental damping
- 2 MV, beam driven
- 1 kW RF for amplitude lock
- Multipacting suppressed
56 MHz SRF Cavity for beam storage at RHIC

- Bellow
- Tuning Plate
- Corrugation
- Helium Vessel
- Cavity Gap
- Cooling Channel
- Stiffening Bar
- Fundamental Port
- HOM port
RHIC 28 MHz Accelerating cavity

- SBIR at Niowave
- Very low frequency
- Very large tuning range
- Folded structure
- Very challenging!

Cavities for RHIC: 4
Frequency: 28.1 MHz
Gap voltage: 600 kV
Tuning range: 200 kHz
Tuning rate: 22 kHz/s
Aperture: 0.1 m
SRF electron guns

- Fast growing application for QWR, 3 so far.
- Important for various applications, in particular CW high-brightness beams for FELs and ERLs.
- Niowave in collaboration with various institutes.
- Quick design – to – test cycle.
- At this conference, also talk by Sergey Belomestnykh MOPO055
## BNL-U. Wisc.-NPS-Niowave SRF Gun Parameters

<table>
<thead>
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<th>Parameter</th>
<th>Units</th>
<th>BNL</th>
<th>U. Wi.</th>
<th>NPS</th>
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<td>Frequency</td>
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<td>Q0 (no cathode, 4.5K)</td>
<td>x10⁹</td>
<td>3.7</td>
<td>3.3</td>
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NPS 500 MHz gun

PRST-AB 14, 053501 (2011)
BNL 112 MHz gun

S. Belomestnykh et al, proc. PAC11
U. Wisconsin 200 MHz gun

- BES funded design for a seeded VUV/soft X-ray Free Electron Laser
- Gun is being fabricated at Niowave with testing beginning next year.
In closing

- The QWR is a simple, ultra-compact, stable and efficient.
- It is a very popular cavity for low β applications.
- The Superconducting QWR is recently finding many applications for very high β.
- These applications include crab cavities, storage ring accelerating and storage cavities and electron guns.
- An enormous advantage in these applications is the outstanding separation of the unwanted modes.