Elliptical Cavities: Proven SRF Option

Terry L. Grimm
Michigan State University

July 2005
Outline

- Multi-cell elliptical cavities
  - Demonstrated for $\beta > 0.4$
  - Future trends
- Multi-spoke cavities
  - Limited experimental results
  - Comparison for RIA
  - Future applications
Multi-gap Structures

- QWR
  - Australian Nat. Uni

- HWR
  - Argonne
  - Frankfurt

- Cylindrical (Elliptical)
  - JLAB
  - JLAB, MSU

- Argonne, ATLAS
- Legnaro
Multi-cell Elliptical Cavities

- Many groups have developed reduced-\(\beta\) cavities
  - CERN, JLAB, JAERI/KEK, Los Alamos, MSU, Milan
  - Same issues as \(\beta=1\) cavities
    \[ E_{\text{acc}} \text{ limited due to peak E and B fields} \]
- Several reduced-\(\beta\) cryomodules have been built
  - SNS, RIA, J-PARC
  - Tested in realistic operating conditions
    - Phase locked, tuner, power coupler, focusing elements,
      HOM dampers, microphonics control
  - Same issues as \(\beta=1\) cryomodules
    - No mechanical instability or limit reached
- Elliptical cavities for \(\beta>0.4\) are proven technology
  - All linac issues addressed (no boogyman)
Prototype $\beta=0.47$ Cryomodule

- Helium Dewar
- Helium Supply
- Support Link
- Outer Magnetic Shield
- Thermal Intercept Shield
- Inner Magnetic Shield
- Alignment Viewport
- Titanium Alignment Rails
- Beta - 0.47 Superconducting Cavity
- Cavity Tuner
  - Mechanical - Slow
  - Piezoelectric - Fast
- Fundamental Power Coupler & Moveable Transmission Line Transformer

PAC03
LINAC04
Elliptical – Future

• **Future trends for reduced-β**
  • **Apply advances from β=1 community**
    New shapes (low loss, reentrant, half-reentrant)
    High current – BBU/HOM
    ILC industrial/mass production
    cavities & cryomodules
  • **More cells with more velocity grading**
    9-cells with β=0.45, 0.55, 0.67 & 0.85
  • **More frequencies and sub-harmonics**
    1.3 GHz, 1.5 GHz, 650 MHz, 750 MHz, ……
Multi-Spoke Cavities – Experimental Results

• **First cavities recently tested**
  • Double-spoke (1) – 2004
  • Triple-spoke (2) – 2005

• **No cryomodule tests under realistic conditions**
  • Tuner
  • Superconducting solenoid and shield
  • Microphonics control
  • High load per cavity at 4 K
  • HOM couplers and analysis
**Elliptical vs. Spoke for RIA [1]**

- **Detailed Comparison for the Rare Isotope Accelerator**


  - “The proposed alternative based on triple-spokes does not offer any credible advantage over elliptical cavities. Specifically, the merits of the elliptical design compared to the triple-spoke are summarized below ….”

  ![Diagram of elliptical vs. spoke cavities with values for βopt: 0.49, 0.50, 0.63, 0.62, 0.83.](image)
Elliptical vs. Spoke for RIA [2]

- **Cost estimates nearly identical**
  - Elliptical – more cavities, but more per cryomodule
  - Spoke – more niobium, electron beam welding and complicated helium vessel

- **Prototype elliptical cryomodule demonstrated**

- **Design peak magnetic field on surface for cw operation**
  - Elliptical – 70 mT at 2 K
  - Spoke – 82 mT at 4.5 K

- **Cryogenic requirement**
  - Elliptical – 7 kW at 2 K
  - Spoke – 25 kW at 4.5 K
  - Cost & electrical usage are comparable
Elliptical vs. Spoke for RIA [3]

- **Liquid He type** – operational stability & microphonics control
  - Elliptical – 2 K superfluid with improved heat transfer and small pressure fluctuations
  - Spoke – 4.5 K with cryoplant pressure fluctuations and large boiling of ~100 W per cavity
- **Higher proton energy using elliptical** (1030 vs. 960 MeV)
- **Beam dynamics (both acceptable)**
  - Elliptical – room temperature quad doublets (easier alignment)
    - larger transverse acceptance
  - Spoke – superconducting solenoids
    - larger longitudinal acceptance
Multi-Spoke Advantage?

- Offer advantage for certain niches around $\beta \sim 0.5$
  - Low transverse emittance – small aperture
  - High longitudinal emittance – low frequency
  - Low current
    - No HOM couplers
    - Small aperture with loss

- Example
  - 10-20 gaps
    - Each cavity is unique (gap changes with velocity)
    - Single rf system with focusing elements between or with rf focusing
Cavity Types & Dimensions

- Gap length = distance traveled in half of an rf period
  \[ = \beta \lambda / 2 = (v/c) \lambda / 2 \]
Single Resonators

QWR

HWR

Cylindrical
(Elliptical)

Legnaro/MSU

Argonne

Legnaro

Argonne

IPN Orsay

JLAB/MSU
Multi-gap Structures [1]

QWR

HWR

Cylindrical
(Elliptical)
Range of Velocities

Range of β’s (β = v/c)

- Application/requirements will drive cavity choice
- For electrons elliptical cavities used from rest to the speed of light (β=0 to 1)
  - Injector uses reduced-β elliptical
  - Main linac uses β=1 elliptical