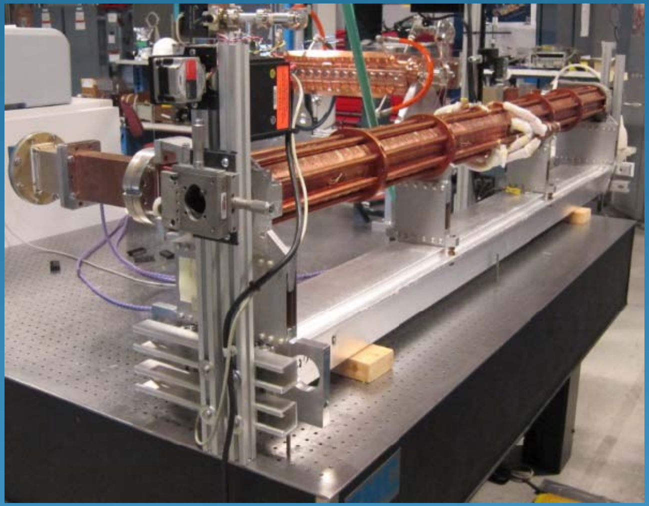
Implementation and Improvement of Bead-pull Technique on Cavity Cells



Li - Chia (Jerry) Tai
Adviser: Dr. Geoff Waldschmidt
Advanced Photon Source (APS), Argonne National Laboratory
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Goals and Contents

- Tune the screwed-up cavity cells
- Look for local reflection coefficient to tune the cells
- Enhance LabVIEW's calculation ability with Mathcad

I. Theory

II. Implementation

III. Improvement

IV. Progress Updates

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I. Theory: 1st assumption

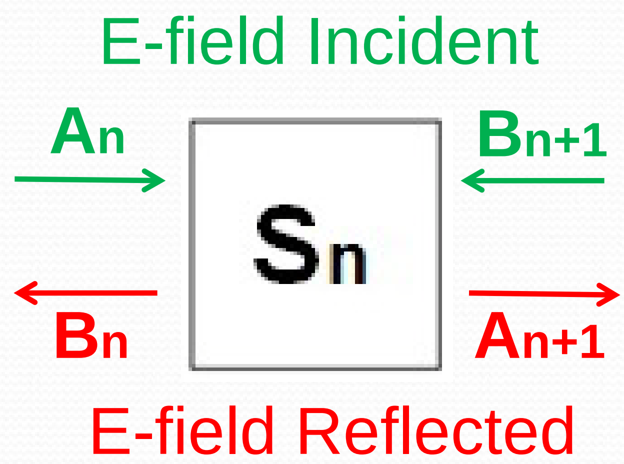
- Each cell is a 2-port network

→ Scattering matrix *Sn* can be defined

Fact:
Sn is 2X2 matrix

Formula sheet:

$$\begin{bmatrix} B_n \\ A_{n+1} \end{bmatrix} = S_n \begin{bmatrix} A_n \\ B_{n+1} \end{bmatrix}$$



I. Theory: 2nd & 3rd assumptions

Fact:

Sn is 2X2 matrix

Sn is unitary

Sn is symmetric

Formula sheet:

$$\begin{bmatrix} B_n \\ A_{n+1} \end{bmatrix} = S_n \begin{bmatrix} A_n \\ B_{n+1} \end{bmatrix}$$

$$S_n = \begin{bmatrix} \Gamma_n & \sqrt{1-|\Gamma_n|^2}\, e^{-j\varphi} \\ \sqrt{1-|\Gamma_n|^2}\, e^{-j\varphi} & \Gamma_n \end{bmatrix}$$

- No energy dissipation

→Energy entering = Energy exiting

→ $|B_n|^2 + |A_{n+1}|^2 = |A_n|^2 + |B_{n+1}|^2$

→ $\left| S_n \begin{bmatrix} A_n \\ B_{n+1} \end{bmatrix} \right|^2 = \left| \begin{bmatrix} A_n \\ B_{n+1} \end{bmatrix} \right|^2$

- Cavity cells are identical

→Power losses the same regardless of propagation direction (reciprocal)

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I. Theory: Find the reflection formula

Fact:
Sn is 2X2 matrix
Sn is unitary
Sn is symmetric

Formula sheet:

$$\begin{bmatrix} B_n \\ A_{n+1} \end{bmatrix} = S_n \begin{bmatrix} A_n \\ B_{n+1} \end{bmatrix}$$

$$S_n = \begin{bmatrix} \Gamma_n & \sqrt{1-|\Gamma_n|^2}\, e^{-j\varphi} \\ \sqrt{1-|\Gamma_n|^2}\, e^{-j\varphi} & \Gamma_n \end{bmatrix}$$

$$\Gamma_n = \frac{-I_{n-1} + 2I_n \cos\varphi - I_{n+1}}{I_{n-1} - I_n \exp(-j\varphi)}$$

- Γ_n

=local reflection coefficient at cell #n

- φ

=phase difference

$$|\Gamma_n| << 1, \quad \sqrt{1-|\Gamma_n|} \approx 1$$

$$I_n = A_n + B_n$$

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I. Theory: Bead-pull Technique

S_{11p} and S_{11u}

↓

Steele's equation:

$$2P_i(S_{11p} - S_{11u}) = -j\omega k I^2$$

↓

$I = I_n$

↓

Reflection formula:

$$\Gamma_n = \frac{-I_{n-1} + 2I_n \cos\varphi - I_{n+1}}{I_{n-1} - I_n \exp(-j\varphi)}$$

↓

Γ_n

- Satisfies Steele's equation
- P_i = input power,
- S_{11p} = global reflection with object,
- S_{11u} = global reflection without object
- ω = angular frequency of the field
- k = constant depending on geometry of the object
- I = E-field at the object's position before the object perturbs the field

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II. Implementation

S_{11p} and S_{11u}

↓

Steele's equation:

$$2P_i(S_{11_p} - S_{11_u}) = -j\omega k I^2$$

↓

$I = I_n$

↓

Reflection formula:

$$\Gamma_n = \frac{-I_{n-1} + 2I_n \cos\varphi - I_{n+1}}{I_{n-1} - I_n \exp(-j\varphi)}$$

↓

Γ_n

Network Analyzer

NATIONAL INSTRUMENTS LabVIEW

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III. Improvement

Enhancing LabVIEW's calculation ability with Mathcad

Network Analyzer

NATIONAL INSTRUMENTS LabVIEW

Mathcad

NATIONAL INSTRUMENTS LabVIEW

But I am complicated

We chat?

Sure!

I understand

Returns "scattering parameter" S_{11} of a cavity cell

Acquires S_{11} from Network Analyzer

Perform calculations

Acquires results from Mathcad

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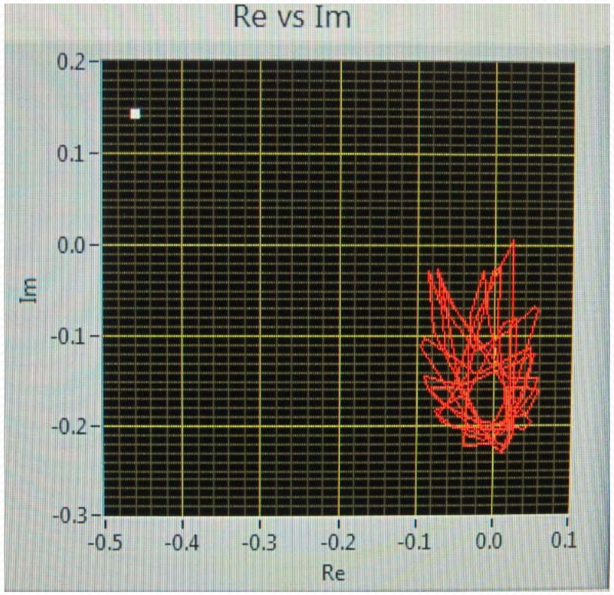
IV. Progress Updates

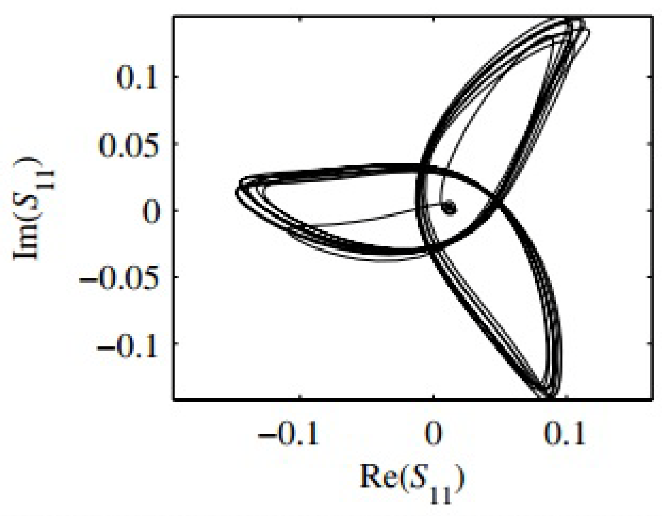
Currently:

- LabVIEW codes to get data with bead-pull technique ✓
- LabVIEW-Mathcad interface for enhanced computation ✓

In progress:

- Tune the cavity to obtain reasonable plots





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Reference

[1] D. Alesini et al. "Tuning procedure for traveling wave structures and its application to the C-Band cavities for SPARC photo injector energy upgrade." *Journal of Instrument*, vol. 8, Oct. 2013.

[2] J. Shi et al. "Tuning of Clic accelerating structure prototypes at CERN." *Proc. LINAC*, 2010.

Thank You

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