R&D of C-band Accelerating structure at SINAP

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Compact XFEL mini-workshop
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Outline

• Acknowledgement
• Background
  – Era of hard X-ray FEL
  – C-band linac for Compact XFEL at SINAP
• C-band accelerating structure
  – Layout of 1st structure
  – Simulation of coupler matching
  – Cold test of experimental model
  – Fabrication of high power test model
• Field measurement and tuning platform
  – Non-resonant perturbation theory
  – Cold test measurement system
• Next step for R&D of C-band
• Summary
Acknowledgement

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• Dr. Sakurai, Dr. Bizen in SPring-8

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Era of Hard X-ray FEL has arrived (LCLS, April 2009)

<table>
<thead>
<tr>
<th>Facility</th>
<th>Energy (GeV)</th>
<th>Distance</th>
<th>Band</th>
</tr>
</thead>
<tbody>
<tr>
<td>LCLS</td>
<td>14.3</td>
<td>~2km</td>
<td>S-Band</td>
</tr>
<tr>
<td>Euro-XFEL</td>
<td>17.5</td>
<td>~3km</td>
<td>L-Band</td>
</tr>
<tr>
<td>XFEL/SPring-8</td>
<td>8</td>
<td>700m</td>
<td>C-Band</td>
</tr>
</tbody>
</table>
C-band Linac for compact XFEL at SINAP

1. A compact hard X-ray FEL is proposed at SINAP close to SSRF.
2. The length of this facility is about 600m.
3. At least, 40MV/m gradient is required for 300m 6.5GeV Linac.
4. C-band RF technology is on development for XFEL at SINAP.
C-band accelerating structure – 1\textsuperscript{st} structure

Scheme:

- Frequency: 5712MHz;
- Length: about 1m;
- Mode: $2\pi/3$, Disk-loaded;
- Structure: Constant Impedance;
- Group velocity: 1\%*$c$;
- Waveguide coupler: Electrically-coupled, two ports;
- No. of cells: 53 regular cells and 2 matching cells.
Coupler matching by CST

Waveguide coupler is adopted to avoid magnetic heating and high electric field. To large extent, it can suppress RF breakdown.

Scanning parameters:
- $a$: Coupled iris radius
- $b$: Matching cell radius
- $r$: Coupled iris thickness
- $d$: Matching cell length

N. M. Kroll.
2000, SLAC-PUB-8614
Matched field and phase distribution on axis

Normalized Electrical Field Distribution

Phase (Celsius degree)

Distance z/mm

Vp=0.6c

289.9

179.5

-179.4

-293.7

-293.7
Experimental models (Shanghai and Beijing)

Horizontal platform in Shanghai
12 cells + 2 couplers

Vertical platform in Beijing
13 cells + 2 couplers
Tuning research (First 5 cells in Tsinghua University)

Tuning tools
The results

According to measurement, resonant frequency is about 5708MHz, so 2 tuning holes for each cell are enough for the tuning target 5712MHz.

360 degrees stands for 1mm, so it’s about 7MHz frequency tuning per 1 mm.
Non-resonant perturbation tuning for experimental model

To large extent, the results agree with the simulation, and finds some tuning methods which is a good reference for the high power model tuning.

Before tuning
SWR>2

After tuning
SWR is about 1.1
Fabrication of high power test model

Next step:
1. couplers are assembled with experimental regular section and tuned;
2. The whole structure will be bonded;
3. At last, the whole structure will be tuned to matched status.
Field measurement and tuning

Field measurement on axis

\[ 2P_i(S11_p - S11_a) = -j\omega kE_a^2 \]

Field tuning on axis

\[ S11_n e^{j\theta_n} = \left( b_n e^{j\phi_n} - b_{n-1} e^{j\phi_{n-1}} \right) / a_n e^{j\psi_n} \]

\[ | S11 e^{j\theta_{\text{tuning}}} - S11^0 e^{j\theta} | = \text{imag}(S11_n e^{j\theta_n}) \times Kn \]

a_n is incident wave and b_n is reflected wave of nth cell, S11n: reflection coefficient of nth cell

T. Khabiboulline et al.
1995, DESY M-95-02
Nonresonant perturbation system

This system for electric field measurement and structure tuning, is based on Nonresonant perturbation theory, it’s composed of network analyzer, step motor system and computer. A LABVIEW code in computer controls the whole system.
The system in Shanghai is a horizontal platform now, and a vertical system will be established at next step.
Control panel of field measurement

- Start
- Stop
- Motor Back

Configuration/Measurement | Error Control | Error Information

- Field amplitude
- Phase
Field tuning

Restore field distribution
Microwave mini-lab
Next step for R&D of C-band

• High power test bunker is in the process of establishment.
• The 1st C-band accelerating structure will be tuned and bonded as soon as possible, and the design of 2nd structure will be started up.
• Pulse compressor is in the process of design: SLED-I or SLED-II?
• Improvement of Microwave Lab
• Research on HOMs and dark current of C-band structure.
Summary

- C-band RF system R&D is started up as the process of C-band accelerating structure research for XFEL at SINAP.
- Design and cold test study have great progress, and it’s a basic accumulation for next C-band accelerating structure research.
- Microwave lab has basic function for field measurement and tuning.
- High power test bunker is in the process of establishment.
- SLED-II design and improvement of microwave lab will be started up as soon as possible.
Thank you for your attention!!!!!

Questions and Discussion