DESIGN AND TEST OF CBPM PROTOTYPES FOR SHINE

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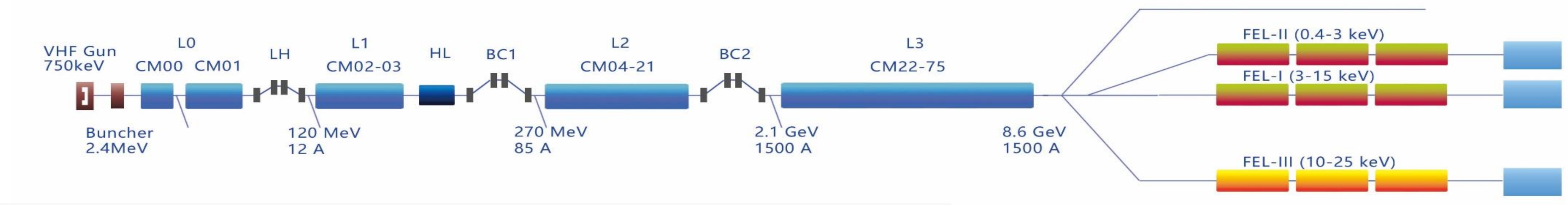
Abstract

SHINE (Shanghai High repetition rate XFEL aNd Extreme light facility) is designed to be an extremely high-performance hard X-ray free electron laser facility located at Zhangjiang, Shanghai. As one of the key parameters of the facility, the resolution of the beam position measurement in the undulator section is required to be under 200 nm at a low bunch charge of 100 pC and better than 10 um at 10 pC. To achieve this, a pre-study based on cavity beam position monitors is under development. Four sets of cavity monitors with different frequencies or load quality factors have been designed and are now manufactured by four different companies. It aims to select the cavity with the best performance and select the most capable company.

Introduction



Parameters	Nominal	Range
Beam energy/GeV	8.0	4-8.6
Bunch charge/pC	100	10-300
Max rep-rate/MHz	1	up to 1
Pulse length/fs	20-50	5-200
Peak brightness	5×10^{32}	1×10^{31}-1×10^{33}
Average brightness	5×10^{25}	1×10^{23}-1×10^{26}

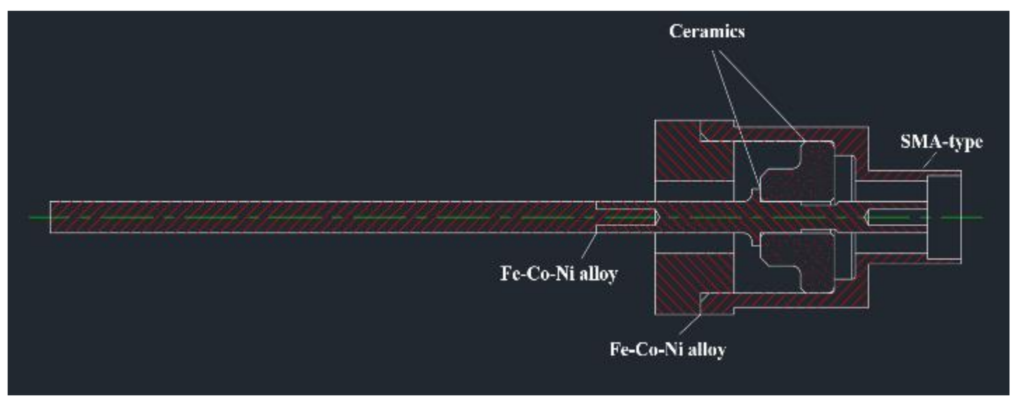
- Target position resolution:
  200 nm @ 100 pC
  10 um @ 10 pC
- Cavity Beam Position Monitor Based

Motivation

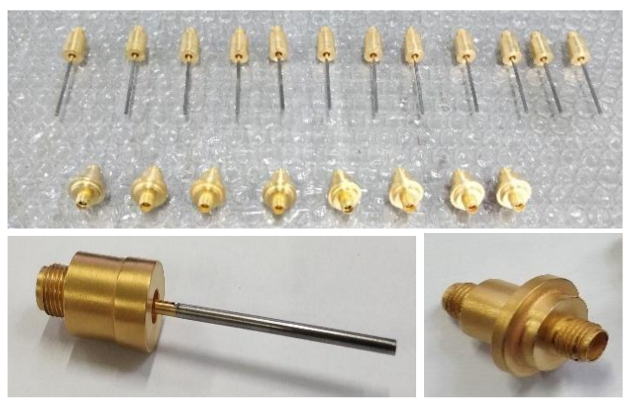
Development of four types of CBPMs:

- **Choose the cavity parameters with best performance**
  - Frequency: C-band or X-band ?
  - Q_{load}: High Q or Low Q ?
  - Cavity structure ?
  - Difficulty in manufacturing ?
- **Choose the most capable company**
  - Manufacturing capabilities & efficiency

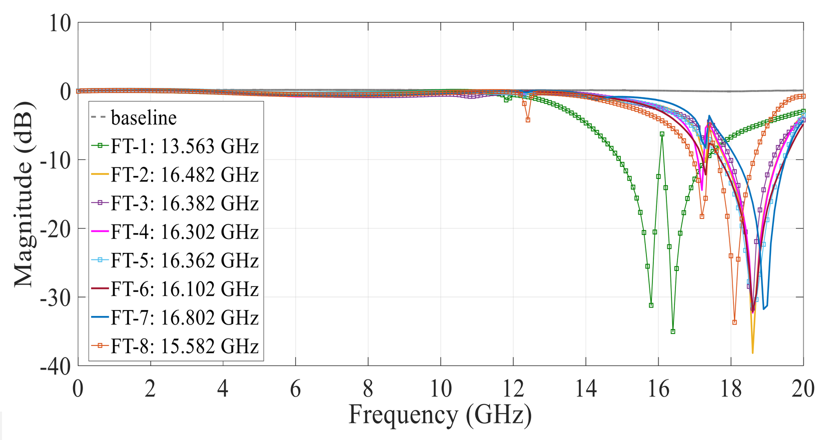
Development of high-bandwidth feedthroughs



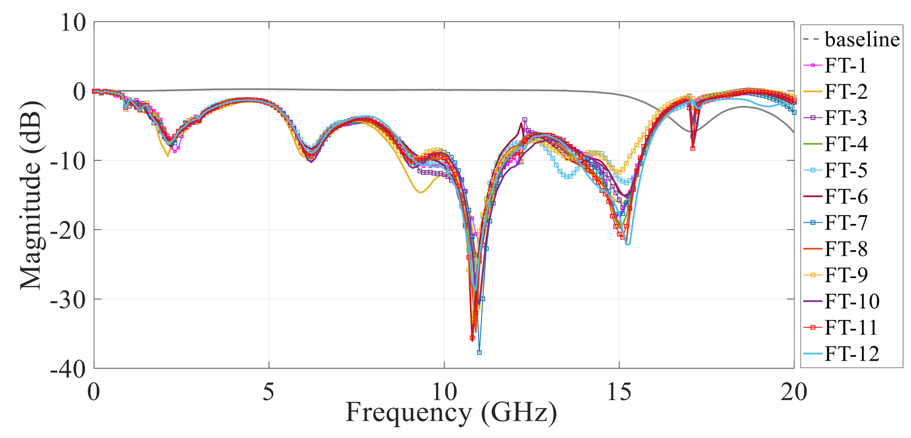
- Low bandwidth of commercial feedthrough
- (6~8 GHz，cannot used in X-band CBPM)
- Expensive of customized X-band feedthrough
- High-bandwidth N-type feedthrough has been successfully designed by Dr. Yuan



- 8 dual-port SMA prototypes
  - Evaluate bandwidth
  - Evaluate consistency
- 12 SMA type feedthrough
- Gold-plated test



S21 test (dual-port SMA feedthrough)
- All 8 prototypes can be used in X-band;
- The bandwidths of the 7 prototypes > **15.5 GHz**, except for the first one



S11 test (single-port SMA feedthrough)
- Good consistency;
- Successfully developed;

Development of CBPM

- **Design parameters of the four CBPMs**
  - Evaluate the impact of frequency on system performance;
  - Evaluate the impact of Q_{load} on system performance;

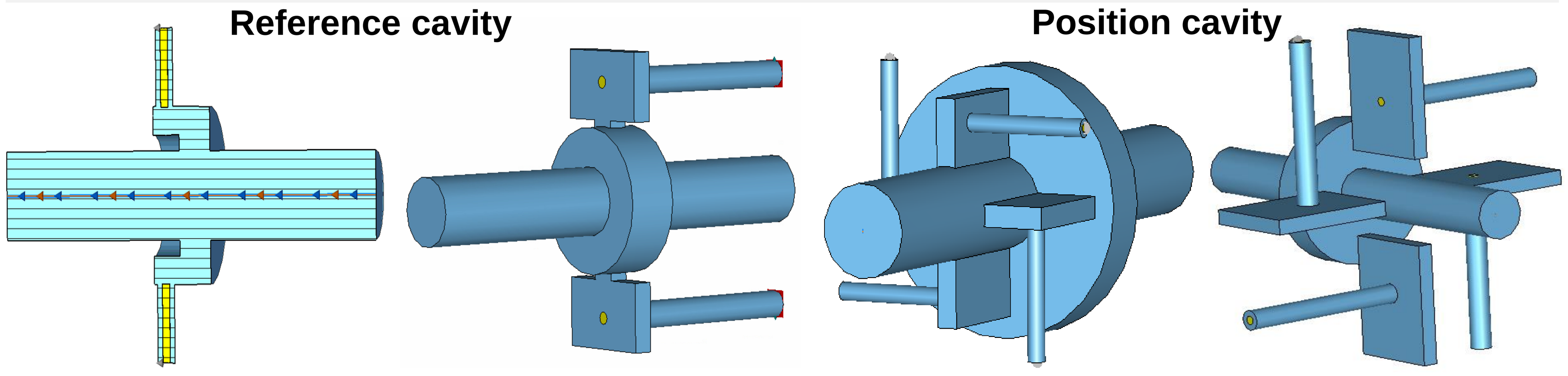
Parameters	CBPM-100	CBPM-200	CBPM-300	X-CBPM
Freq./MHz	5771.5	5771.5	5771.5	11483
τ/ns	100	200	300	100~200
Qload	1813	3626	5440	3611~7222
BW/MHz	3.18	1.59	1.06	1.59~3.18

- **Cavity radius & Frequency dependency on radius**
  - Compacter size of X-band CBPM;
  - Frequency dependency: X-Ref > X-Pos > C-Ref > C-Pos (Corresponding to manufacturing difficulty)

Cavities	Radius/mm	$\Delta f/\Delta r$(MHz/um)	$\Delta f@20um$
C-CBPM Ref.	19.9	-0.3	6 MHz
C-CBPM Pos.	31.7	-0.2	4 MHz
X-CBPM Ref.	10	-1.1	22 MHz
X-CBPM Ref.	15.9	-0.7	14 MHz

- **Cavity structure & Simulation results**

Reference cavity / **Position cavity**



Re-entrant structure
- Facilitate frequency tuning
- Convenient for cable connection
- **C-band CBPM**

Dual-waveguide structure
- Extend the distance between the feedthrough and the beam pipe
- **X-band CBPM**

Two waveguide
- Used in SXFEL facility
- **CBPM-100**
- **CBPM-200**

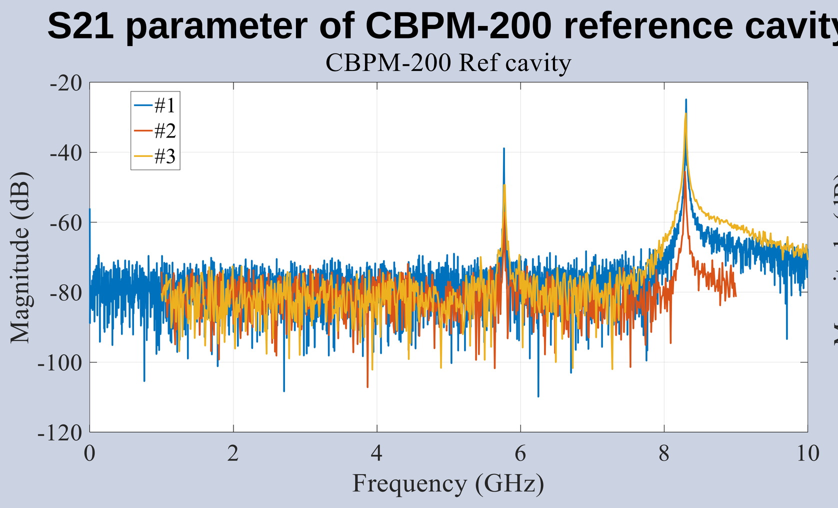
Four waveguide
- Widely used for majority FEL facilities
- **CBPM-300**
- **XCBPM**

Parameter	CBPM-100		CBPM-200		CBPM-300		X-CBPM	
	Ref	Pos	Ref	Pos	Ref	Pos	Ref	Pos
Freq./GHz	5.771	5.771	5.771	5.772	5.772	5.773	11.483	11.483
BW/MHz	3.15	2.92	1.51	1.57	1.21	1.3	1.94	1.81
Qload	1831	1976	3825	3681	4751	4443	5916	6349
Decay time/ns	101	109	211	203	262	245	164	176
Vp(V/nC)	12	2	4	0.8	6	1.1	14	2

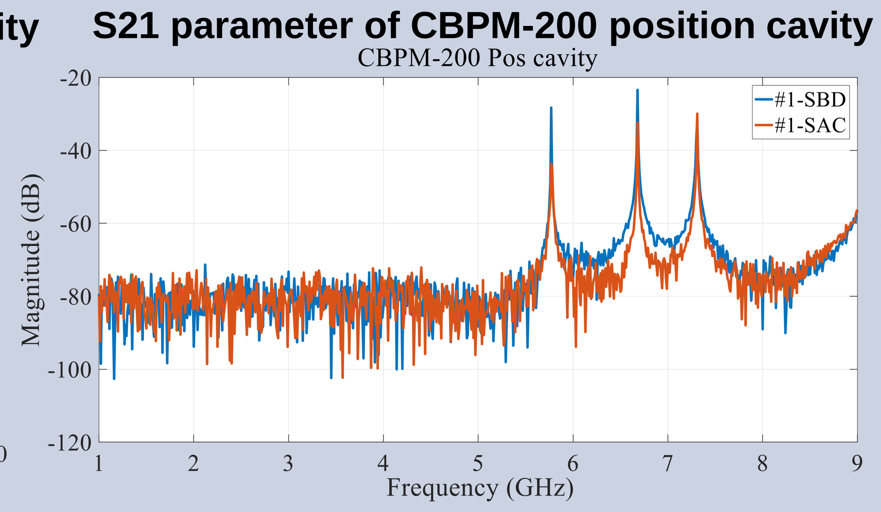
- **Cold test of CBPM-200 (3 sets)**

Photo of CBPM-200

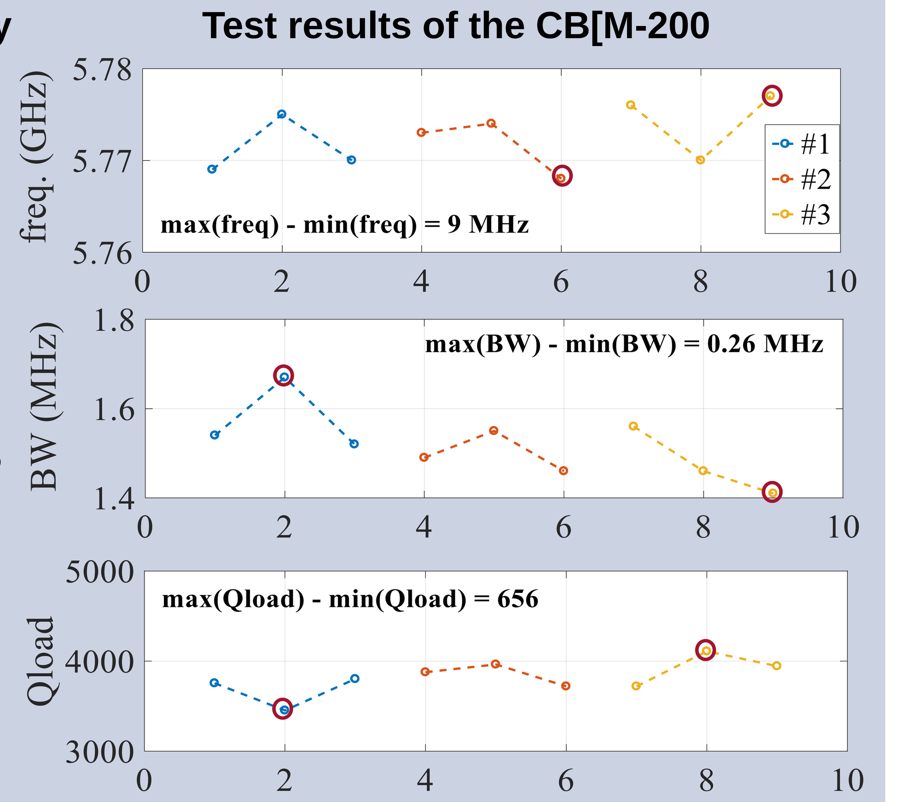
S21 parameter of CBPM-200 reference cavity



S21 parameter of CBPM-200 position cavity



Test results of the CB[M-200



Test results of CBPM-200

Cavities	Freq/GHz	BW/MHz	XY Crosstalk
#1 Ref.	5.769	1.54	~
#1 X	5.775	1.67	-60 dB
#1 Y	5.77	1.52	
#2 Ref.	5.773	1.49	~
#2 X	5.774	1.55	-53 dB
#2 Y	5.768	1.46	
#3 Ref.	5.776	1.56	~
#3 X	5.77	1.46	-54 dB
#3 Y	5.777	1.41	

- 3 sets of CBPM-200 have been manufactured and tested;
- Cold test and vacuum leak test have also been completed;
- The S21 parameter test results of the reference and position cavity show that the two both have good mode separation;
- The XY crosstalk is better than **-50 dB**;
- The maximum frequency difference between the 6 cavities is **9 MHz**, and the maximum frequency difference from the design value is **6 MHz**; the maximum bandwidth difference between the 6 cavities is **0.26 MHz**, and the maximum frequency difference from the design value is less than **0.2 MHz**;
- Overall, the CBPM-200 have met the preliminary requirements, but the results can be further improved in the future.

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