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DESIGN AND STUDY OF CAVITY QUADRUPOLE MOMENT AND ENERGY SPREAD MONITOR *

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Abstract

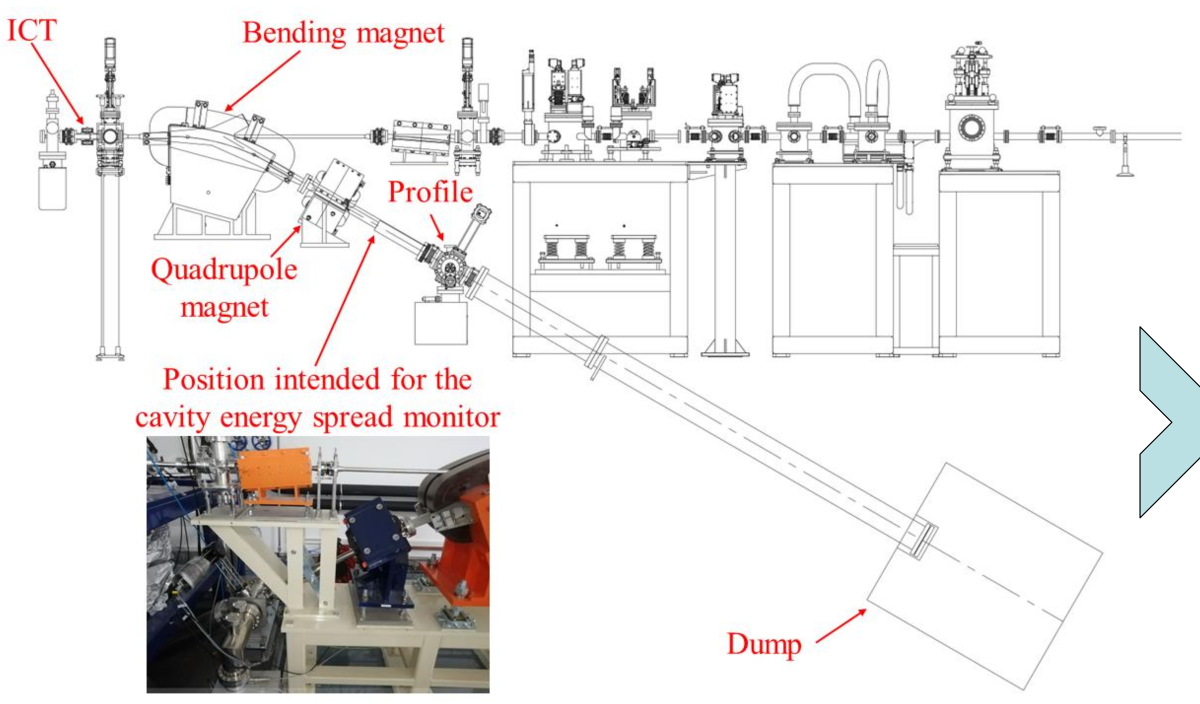
A nondestructive method to measure beam energy spread using the quadrupole modes within a microwave cavity is proposed. Compared with a button beam position monitor (BBPM) or a stripline beam position monitor (SBPM), the cavity monitor is a narrow band pickup and therefore has better signal-to-noise ratio (SNR) and resolution. In this study, a rectangular cavity monitor is designed. TM220 mode operating at 4.76 GHz in the cavity reflects the quadrupole moment of the beam. The cavity plans to be installed behind a bending magnet in Dalian Coherent Light Source (DCLS), an extreme ultraviolet FEL facility. In this position, the beam has a larger dispersion, which is beneficial to measure the energy spread. A quadrupole magnet, a fluorescent screen, and a SBPM with eight electrodes is installed near the cavity for calibration and comparison. The systematic framework and simulation results are also discussed in this paper.

INTRODUCTION

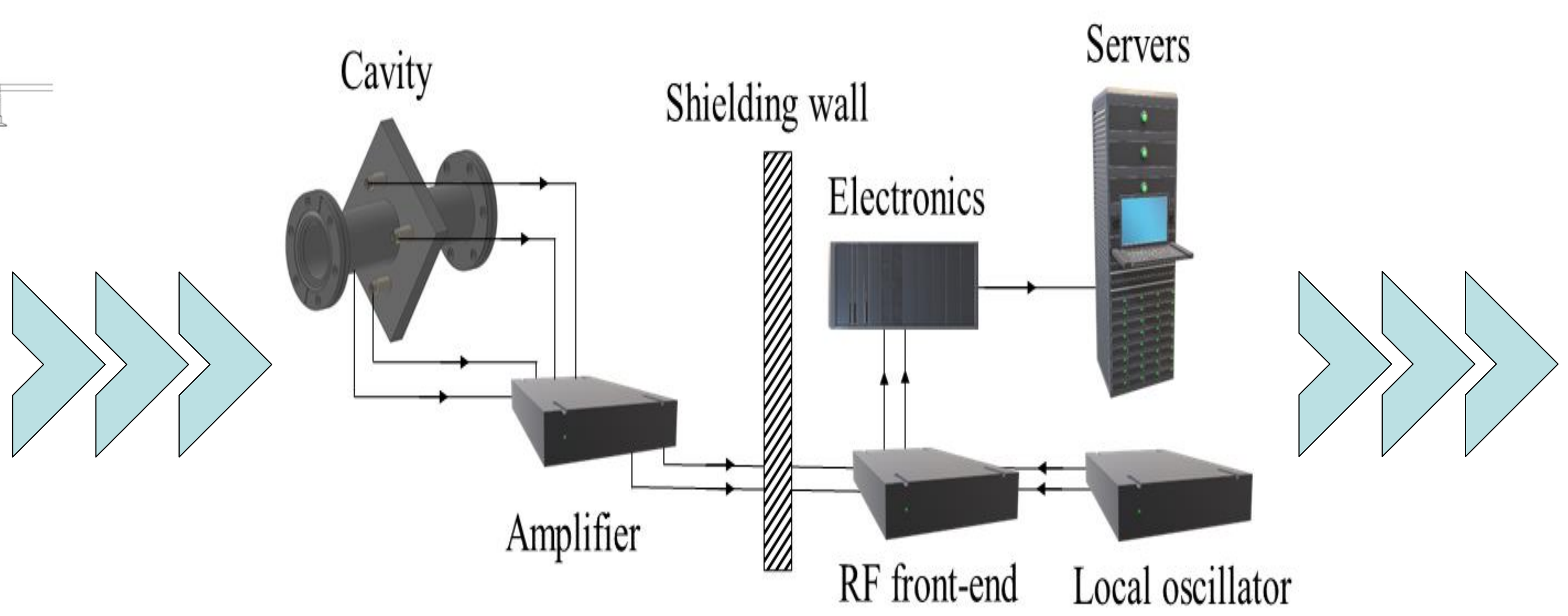
In order to achieve the energy spread measurement with high-resolution, we proposed the method of RF resonant cavity. Similar to SBPMs, cavities are installed at positions with high value of dispersion function, allowing extraction of the beam's quadrupole moment to obtain the energy spread.

Advantages of measuring energy spread using cavity-based method:

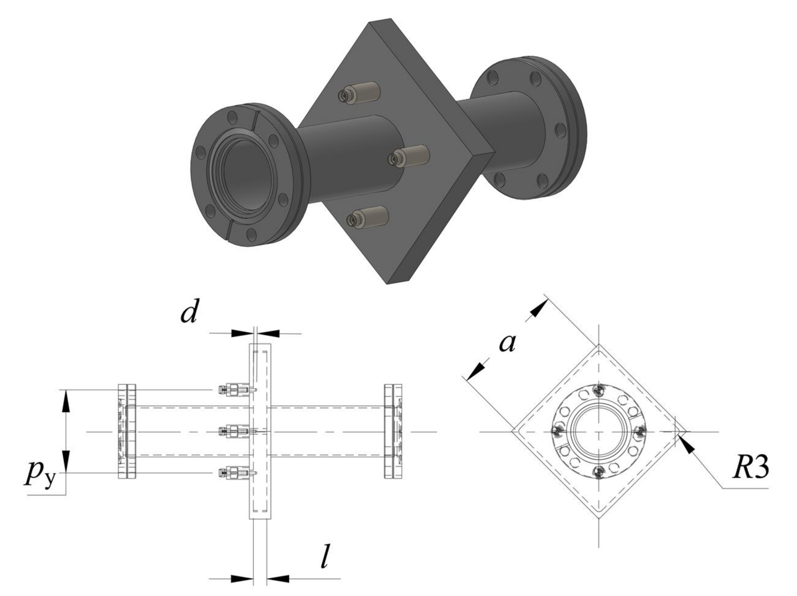
- Compared to placing a fluorescent screen or OTR behind a bending magnet, the cavity is a nondestructive monitor
- In contrast to an SBPM, which can extract quadrupole moments, the quadrupole mode of the cavity has higher SNR and resolution
- The longitudinal dimension of the cavity is very short



Layout diagram



Systematic framework



Parameter	Value (mm)	Parameter	Value (mm)
a	86.2	l	10
p_y	61.8	d	1.4

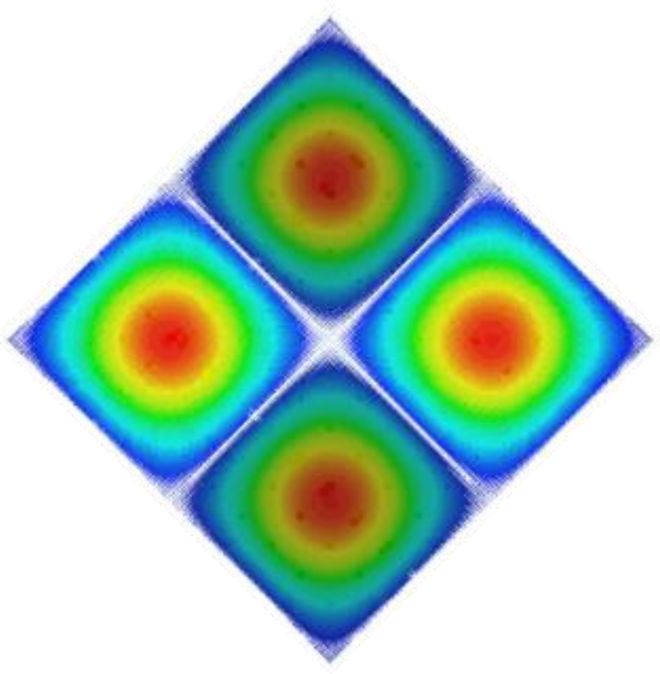
structure of the rectangular cavity

THEORETICAL BASIS

For a rectangular cavity rotated 45° about the axis, its TM220 mode amplitude is proportional to the beam quadrupole moment

$$V_{TM220} \propto x^2 - y^2 + \sigma_x^2 - \sigma_y^2$$

Where x and y are the beam positions in the two direc-tions. σx and σy are the beam rms sizes in the two directions.



Electric field of TM220 mode in rectangular cavity. Warmer colors represent stronger electric fields.

Assuming that the vertical dispersion, η_y, is zero, the relationship between energy spread and quadrupole moment can be written as

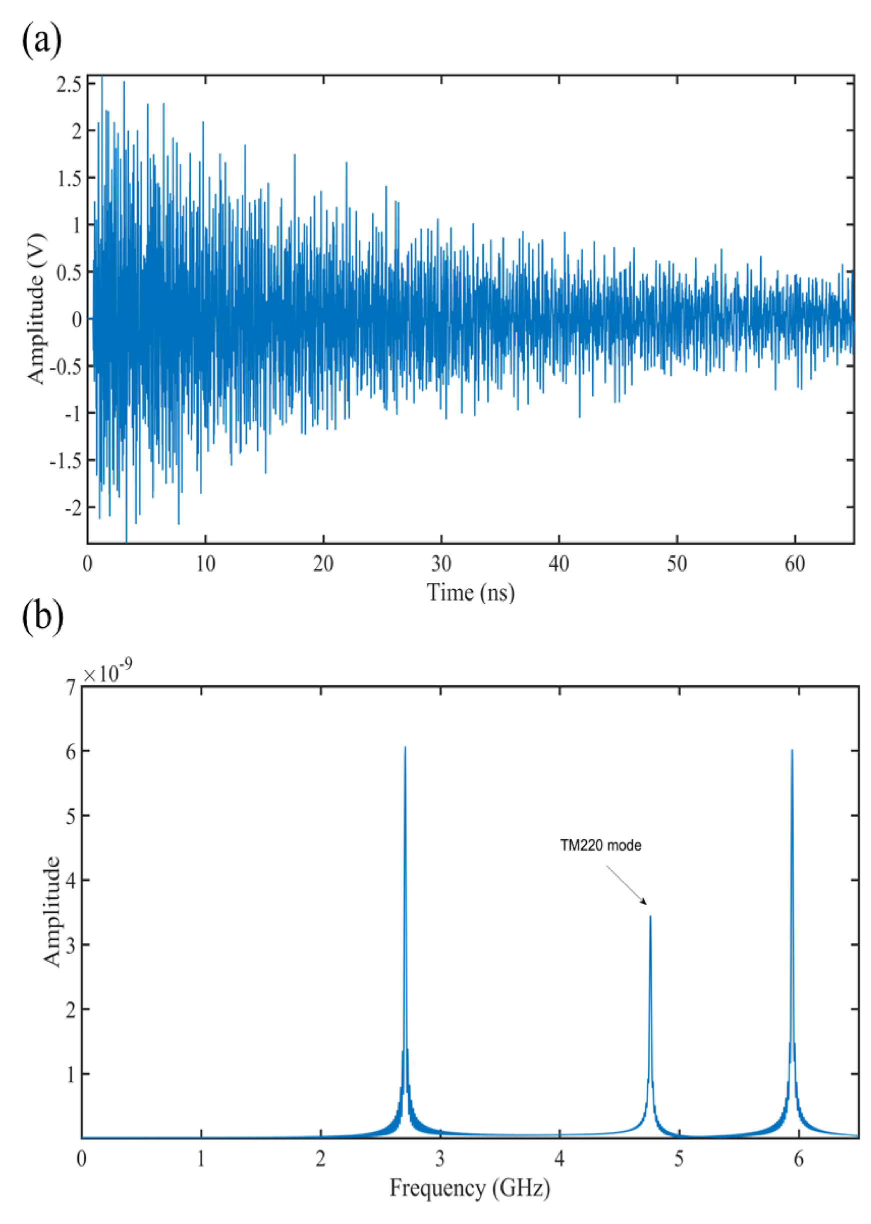
$$\sigma_x^2 - \sigma_y^2 = \beta_x \epsilon_x + (\eta_y \frac{\Delta E}{E})^2 - \beta_y \epsilon_y + g$$

Where β_x and β_y are β functions, η_x is the horizontal dispersion, and ε_x is the horizontal emittance. g is the correction factor, which can be determined by calibration.

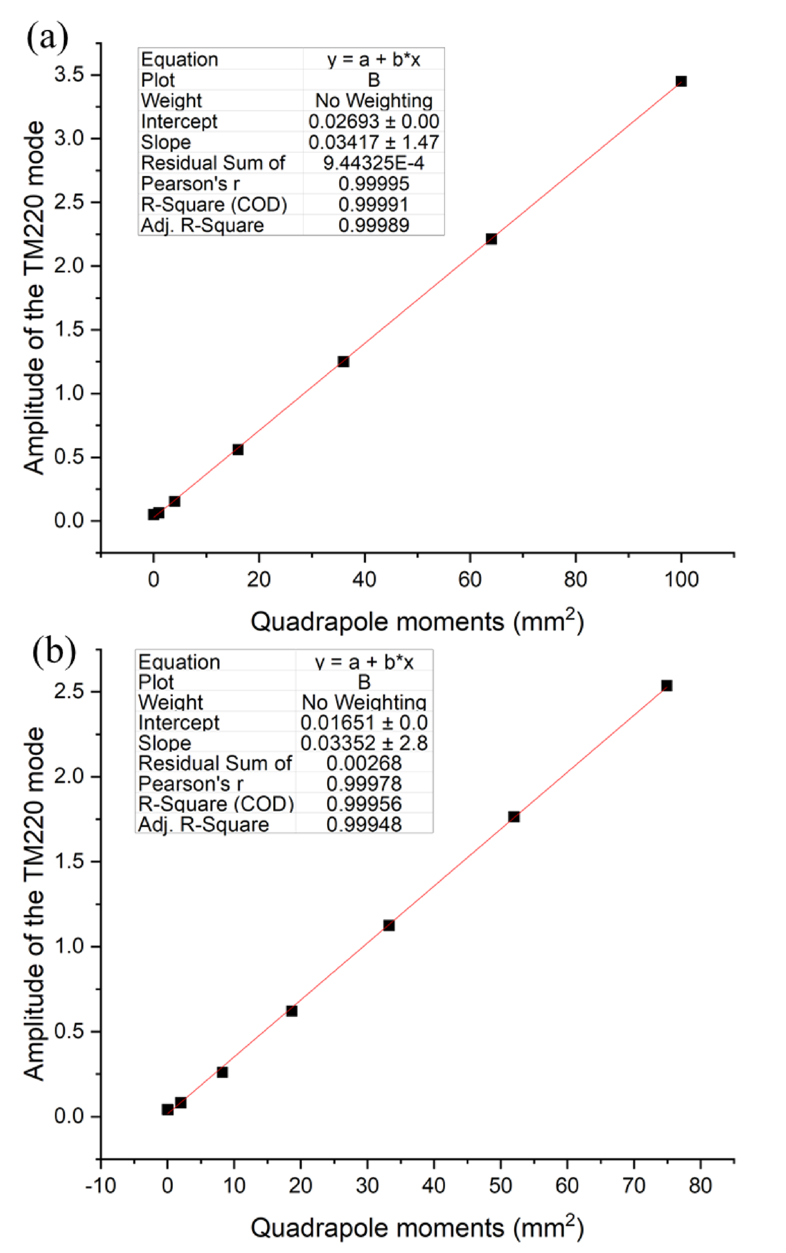
SIMULATION

The cavity model is established in CST, and virtual beams (300 MeV, 500 pC) are loaded for simulation.

The results show that there is a good linear relationship between the amplitude of the TM220 mode and the quadrupole moments.



The output signal of the cavity when beam position $x = 10$, $y = 0$, $\sigma_x = 0$, and $\sigma_y = 0$. (a) is the time-domain signal. (b) is the frequency-domain signal.



Variation of TM220 mode amplitude with beam quadrupole moment. (a) is beam position x varying from 1 to 10 mm when $y = 0$, section size $\sigma_x = 0$, and $\sigma_y = 0$. (b) is σ_y varying from 0.03 to 8.66 mm when $x = 0$, $y = 0$, and $\sigma_x = 1$ mm.

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