# DESIGN OPTIMIZATION OF BUTTON-TYPE BPM ELECTRODE FOR THE SPRING-8 UPGRADE


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## Abstract

The design of a button-type BPM electrode for the SPring-8 upgrade has been optimized from the perspectives of **1) mechanical structure, 2) rf characteristics, and 3) thermal issue.** We have adopted the electrode structure without a sleeve enclosing a button to maximize the button diameter. To minimize the beam impedance and the trapped mode heating of the electrode, the rf structure has been optimized by 3D electro-magnetic simulations. The reduction of the heating suppresses thermal deformation of the electrode and the BPM block, and improves thermal stability of the BPM system. The mechanical tolerance of the electrode was defined to fit the error budget for the total BPM offset error of 100 μm rms.


## Required Performances for the BPM system

**1) Resolution**

| | |
|---|---|
| Single-Pass (SP) mode | 100 μm rms @100 pC single bunch |
| COD mode | 0.1 μm rms @100 mA 1kHz b.w. |

**2) Accuracy**

| | |
|---|---|
| Single-Pass (SP) mode | 100 μm rms (±200 μm max.) before BBA |
| COD mode | 10 μm rms after BBA |

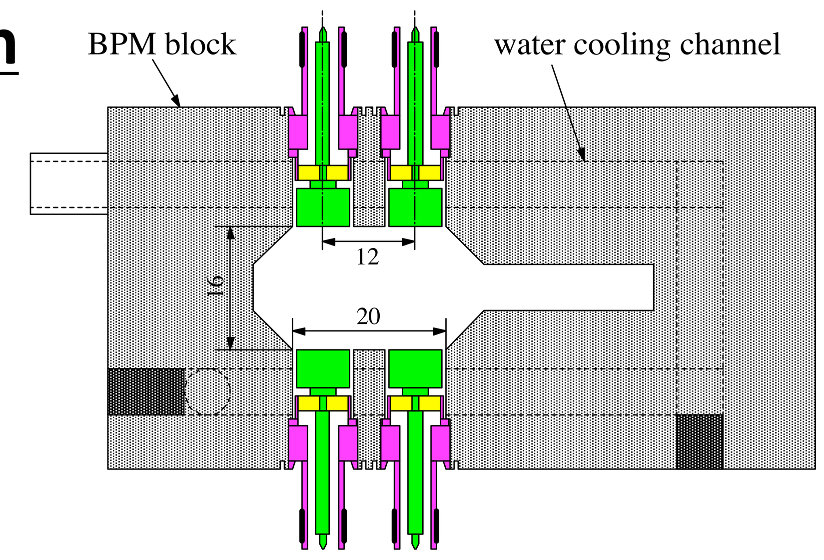
**3) Stability**

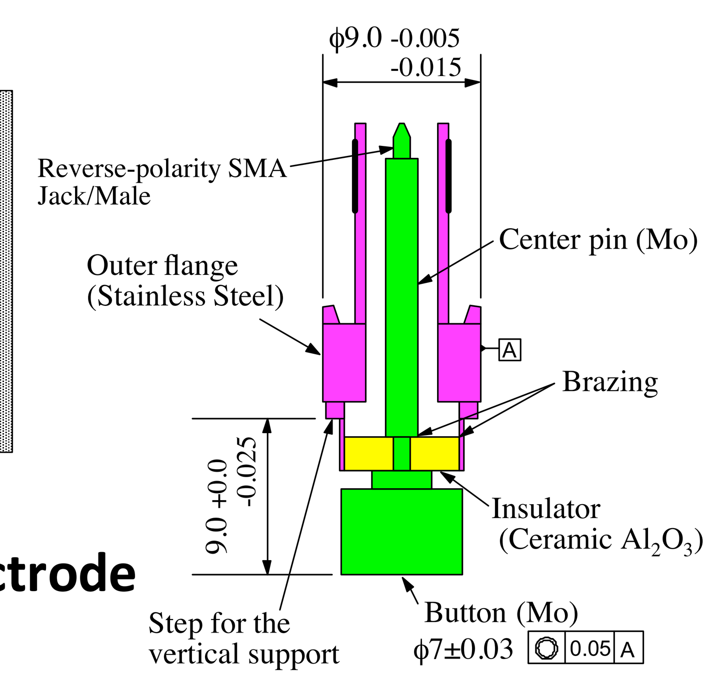
| | |
|---|---|
| Drift of BPM offset | < 5 μm/month |

## Points of the BPM electrode design

1) **Maximization of the signal intensity** to satisfy the required Single-Pass resolution (100 μm rms)
2) **Mechanical tolerance** to fit the error budget of the allowable BPM offset (100 μm rms)
3) **Minimization of the trapped mode heating** to reduce the drift due to the thermal deformation

## Mechanical Design




### Button diameter

**Maximization to obtain sufficient signal intensity**

Button-type Electrode :

- Mounted with the narrow horizontal span of 12 mm.
- **Structure without the sleeve enclosing the button.**

**Maximized Button diameter is ϕ7 mm.**

### Mechanical Tolerances

- **Button diameter ±30 μm**
- **Vertical button position**
  -> **50 μm** as an offset back into the housing hole
- **Horizontal button position**
  -> **Centricity of 50 μm** between the button and the outer flange

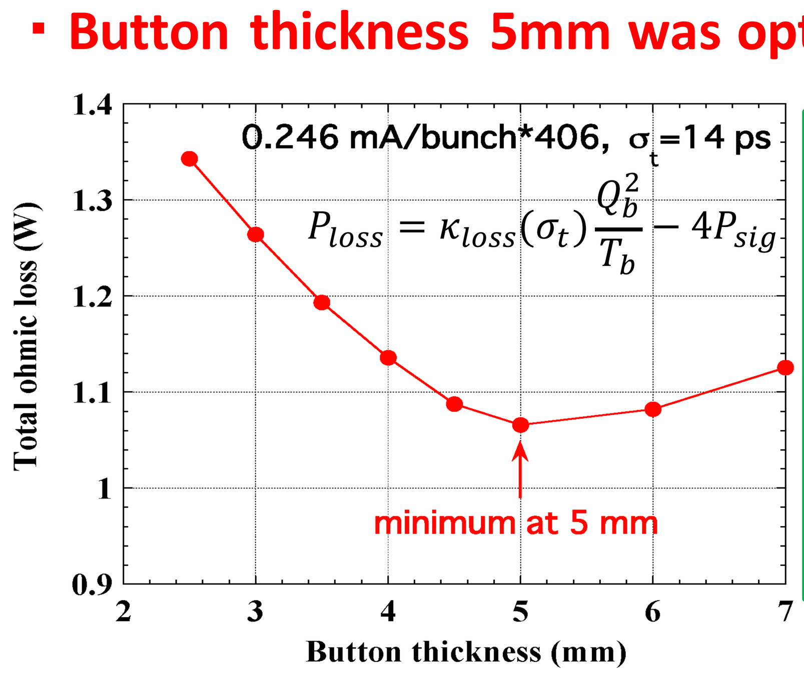
### Materials

- **Water-cooled BPM block, Outer flange of the electrode**
  **-> Stainless steel (316L)**
- **Button and center pin -> Molybdenum (Mo)**
  - Suppression of the trapped mode heating
  - Mo: High electric and thermal conductivity
- **Insulator -> Alumina ceramic ($Al_2O_3$)**
  - Thermal conductivity 18 W/m/K close to that of stainless steel

## RF and Thermal Simulations

### Ohmic Loss Minimization and Trapped Modes Analysis

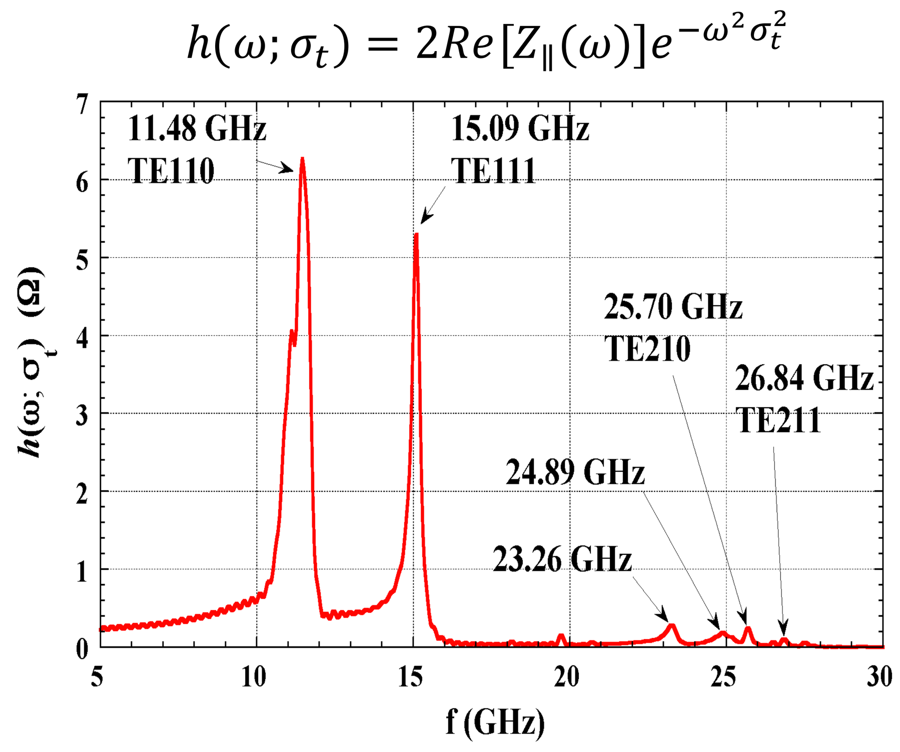
- Trapped resonance modes lead to the heating and beam impedance.
- Main resonance modes excited in a gap between button and housing hole.
- Narrowing the gap simply reduces the resonance strength.
  -> It requires tighter machining tolerance to avoid electric short.
- **We selected the same gap of 0.5 mm** as the electrode of the present SPring-8.
- **Button thickness 5mm was optimized to minimize the total ohmic loss $P_{loss}$.**




Assumed bunch fill pattern of **0.25 mA/bunch*406 gave the maximum heat load** among the equally spaced bunch fill patterns for a total stored current of 100 mA.
Bunch lengthening due to potential well distortion was taken into account. The bunch length $s_t$ is 14 ps for the bunch current of 0.25 mA.

**Frequency spectrum of trapped modes**

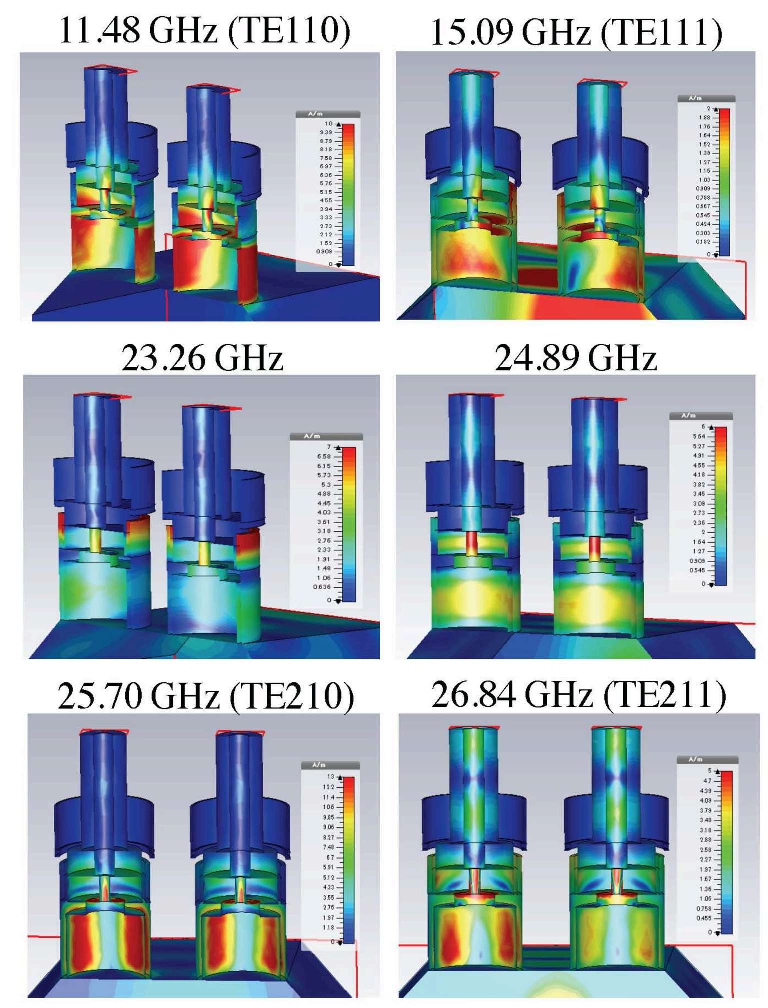
$$h(\omega;\sigma_t) = 2Re[Z_{\parallel}(\omega)]e^{-\omega^2\sigma_t^2}$$




**Loss factor**

$$\kappa_{loss}(\sigma_t) = \frac{1}{2\pi}\int_0^{\infty} h(\omega;\sigma_t)d\omega$$

**Magnetic field distributions**



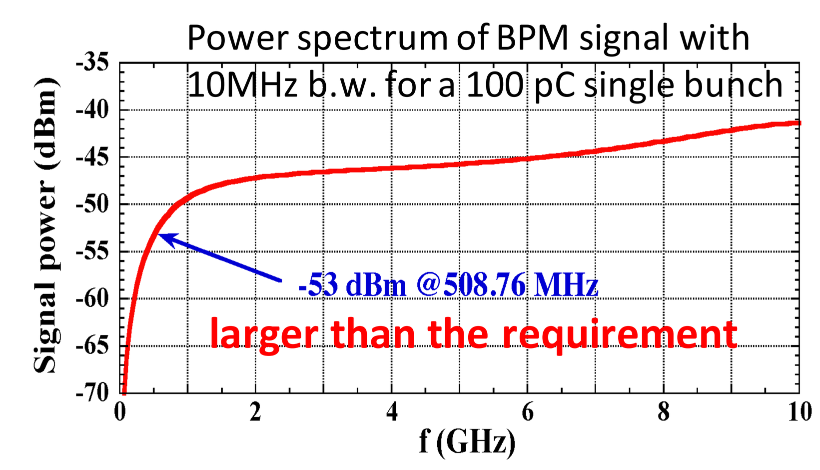

### Signal Intensity

**Required signal voltage** $V > \frac{k_{x,y}}{2\sigma_{resol}}\sigma_V$

➡ **0.38 mV -> -55 dBm**

**Sensitivity coefficients :** $k_x$ = 6.8 mm, $k_y$ **= 7.7 mm**
**Demanded resolution :** $\sigma_{resol}$ **= 100 μm (rms)**

**Equivalent input noise power :**
**-87 dBm ($\sigma_V$ = 10 μV )**
Thermal -101 dBm
NF of BPM electronics including cable loss 14 dB




### Heating of the BPM Electrode and the Block

- For a temporary bunch filling pattern: 0.25 mA/bunch*406 @Total current 100 mA, bunch length 14 ps (rms)
- **The total heat input to the whole of the BPM head -> 1.1 W**
- Estimation of heat input to the button surface, center pin and the inside of housing hole.
- We computed a temperature distribution of the BPM head.

**Heat input condition**