Improvement of Capture Ratio for an X-band Linac Based on Multi-objective Genetic Algorithm

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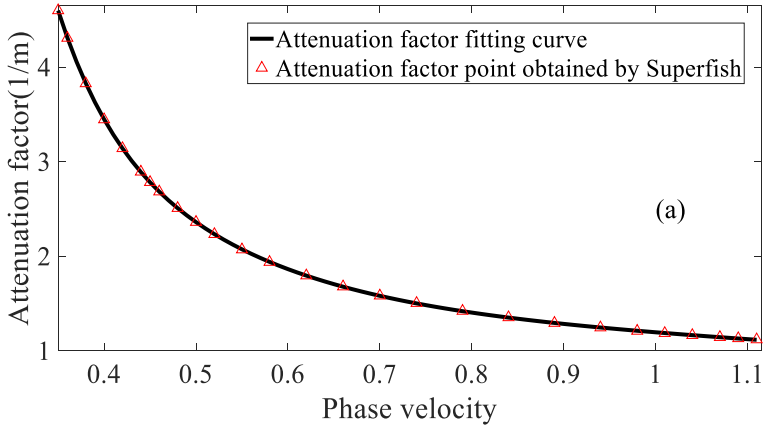
Design consideration

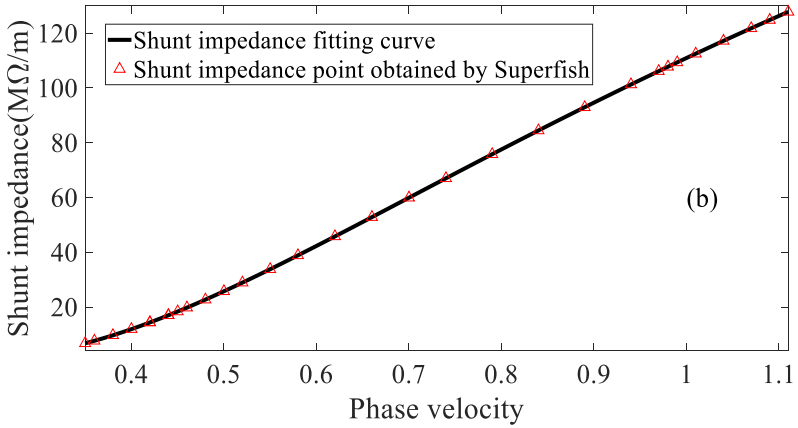
- Obviously, the fitting curves are consistent with the calculation results of SUPERFISH well.



$$\alpha = 25510\exp\left(-\left(\frac{\beta_p + 0.8152}{0.3694}\right)^2\right) + 18.73\exp\left(-\left(\frac{\beta_p + 0.5809}{0.6113}\right)^2\right) + 1.888\exp\left(-\left(\frac{\beta_p + 0.8879}{2.733}\right)^2\right)$$

$SSE = 9.3391 \times 10^{-5}$

$R-square = 1$



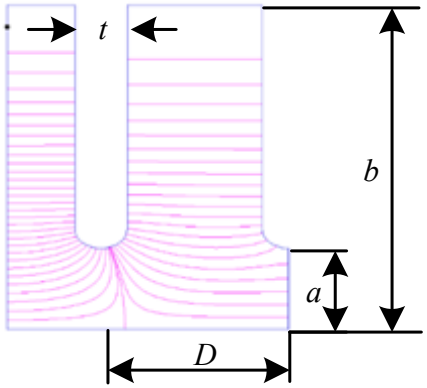
$$Z_s = -132.05\beta_p^{\,5} + 657.31\beta_p^{\,4} - 1320.5\beta_p^{\,3} + 1292.7\beta_p^{\,2} - 434.43\beta_p + 47.908$$

$SSE = 0.0046$

$R-square = 1$

Design consideration

- simplify the structure design and realization, the same iris radius is used here



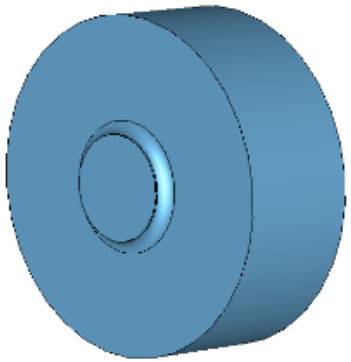
1.5cell in SUPERFISH

D : cavity length

a : iris radius

b : waveguide radius

t : iris thickness



three-dimensional model

- Combining previous literatures and engineering experiences, the structure of six-segment cavity chain is adopted

	1	2	3	4	5	6
$\beta_{p\min}$	0.36	0.50	0.72	0.92	0.96	0.98
$\beta_{p\max}$	0.43	0.57	0.75	0.95	0.97	0.99
Number of cells	4	5	5	6	6	16

Design consideration

- *capture ratio*

$$\eta = \frac{M}{N} \times 100\%$$

N: the initial number of electrons in a period $[-360^{o},0]$

φ: the median phase of these N electrons at the last cell

M: the number of electrons whose phase at the last cell is $[\varphi_1 - 180^{o}, \varphi_1 + 180^{o}]$

- *energy spread*

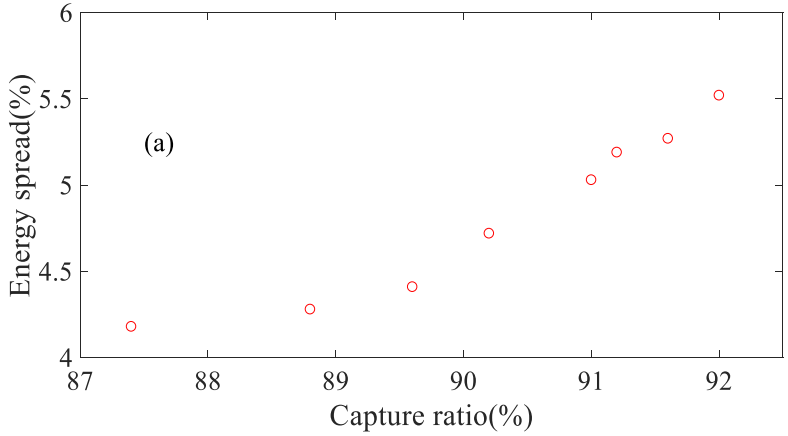
$$\sigma = \frac{1}{\overline{W}} \sqrt{\frac{1}{M} \sum_{i=1}^{M} \left(W_i - \overline{W} \right)^2}$$

W_i: last energy of different initial phase

$\overline{W}$: average energy

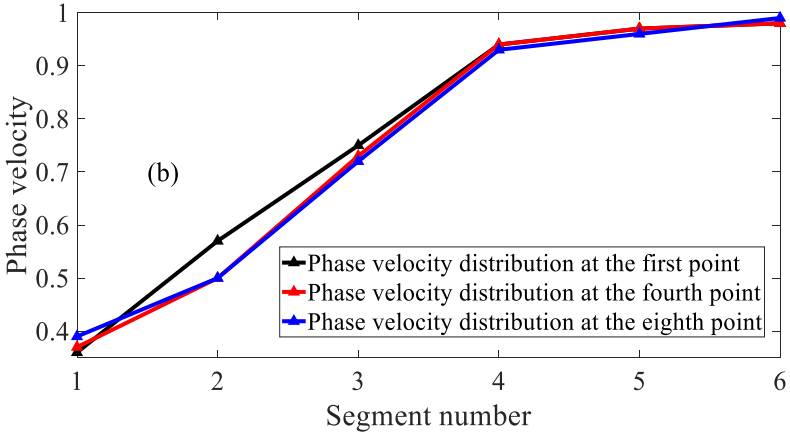
Simulation

- The eight Pareto front points obtained by NSGA-II



- capture ratio: 87.4% -92.0%
- energy spread: 4.18% -5.52%

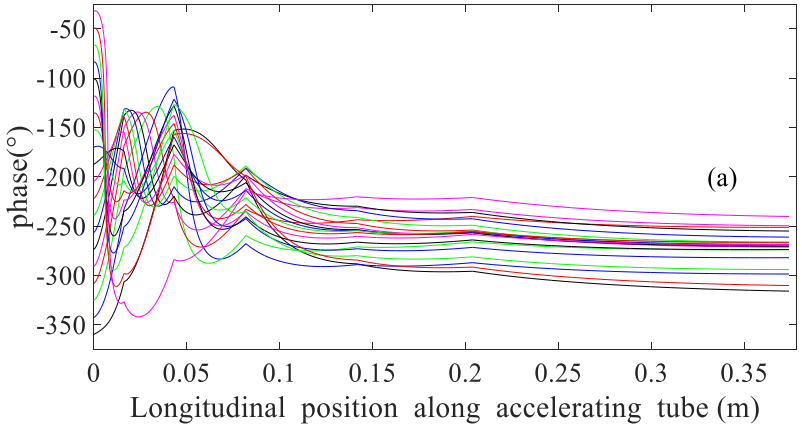
- take the representative points 1, 4, and 8 to plot the corresponding phase velocity distribution

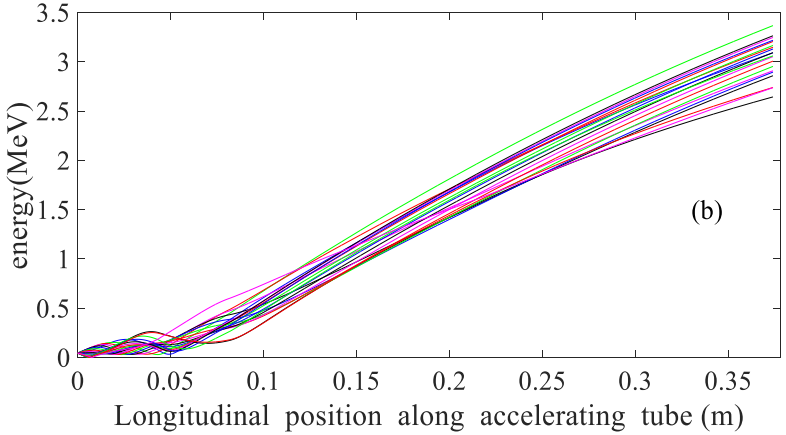


capture ratio and energy spread are related to the first two segments of the cavity chain

Simulation

- The sixth pareto front point is selected to analyse the movement process of electrons in TW accelerator





The particles of 328° can be captured

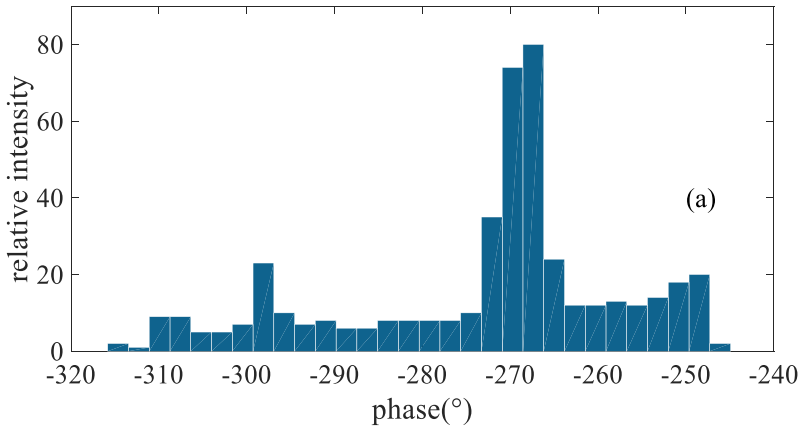
Capture ratio: 91.2%

Captured electrons oscillate in phase

Oscillating and increasing

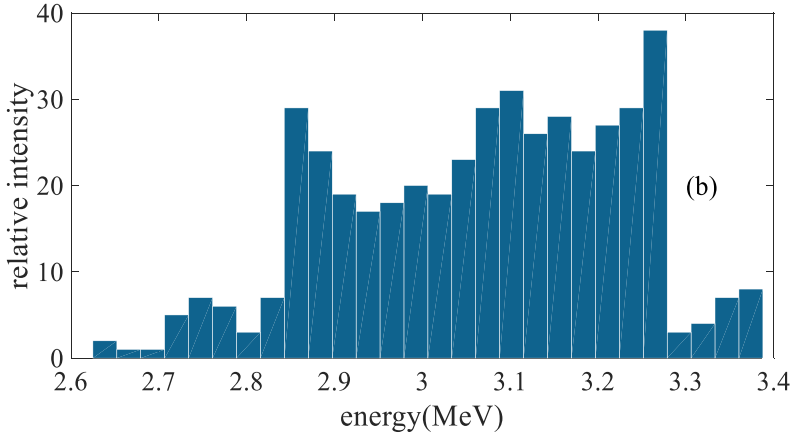
Simulation

- To analyse the capture ratio and energy spread



The phase are compressed to 75°

Most are concentrated at the maximum acceleration phase of -270°



The energy is distributed within

2.6~3.4MeV

Most are concentrated in

2.9~3.3MeV

Energy spread : 5.19%

CONCLUSION

- The fitting model is feasible and improves the efficiency of algorithm.

- Based on NSGA-II, the phase velocity distribution with high capture ratio and low energy spread is obtained, which provides the design basis for ~MeV TW cube that can be used in industry.