A NEW TYPE SW LINAC USED IN INDUSTRIAL CT

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Abstract

A new type S band SW electron linac used in Industrial CT was designed and developed. Energy of electrons can reach 9Mev(pulse current intensity 150mA). The new type on-axis accelerating structure was operated in the π/2 mode and 2856MHz.The designed beam focal spot size is 1~1.5mm(without external focusing system). The calculation of particle dynamics, the result of main parameters' measurement, and CT imaging test etc are given.

INTRODUCTION

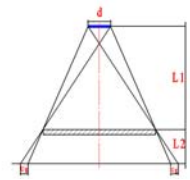
As an important NDT or NDE tool, Industrial CT overcomes the deficiencies of traditional X-Ray imaging system, and widely used in medicinal inspection, archaeology study etc.. Especially the high energy Industrial CT (based on accelerator) can examine large scale and high-density workpieces for its strong penetrability. The high energy ICT based on LIA appeared long time ago, and for its volume is so large and its technology is complicated, now days the high energy based on RFA has being the replacement of the LIA type ICT. For example the high energy ICT product of the famous ARACOR company, BIR company and HYTEC company chose RFA as the high energy X source.

Also we has developed a new type S band SW electron linac used in ICT. Before discussing the design of new type electron linac, we would discuss the request of accelerator X ray source for CT imaging.

For assuring the space resolution of CT imaging, we hope the X ray source size d is small enough because the finite size of X ray source would bring the geometry blur Ug, which will make the image boundary blurry and if the defect size x is too small, the X ray source size d must be reduced so that the defect can be detected (Fig.1, Fig.2) explicitly. The Ug definition is the following

$$U_g = \frac{dL_2}{L_1} = dM \qquad (1)$$

The M is the geometry magnifying multiple of the imaging system and the d is X ray source size in above formula. Here L1 means the object distance and L2 is the image distance.



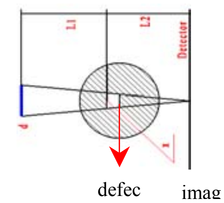


Figure 1: Geometry blur. Figure 2: Defect resolution.

So in the design of accelerator, we had to reduce the electron beam transverse size, which is the main method to increase the space resolution in CT imaging. Besides the beam intensity must be big enough so the dose by the electron beam collide the target can satisfy the high energy ICT's imaging.

Usually, there are two way to produce such electron beam, one is that installing external magnet focusing system and focusing the electron beam, another is to design new type RF accelerator without external focusing system, by the weak focusing force of new RFA to reduce the size of electron beam. Jointing the high Z target (e.g. metal W) at the electron beam way out of RFA, which would directly form high energy X source.

THE DESIGN OF NEW SW LINAC USED IN INDUSTRIAL CT

Considering the request of CT imaging that is acquiring the small beam spot, we increased the weak focusing effect by taking the nose structure in accelerating cavity and put it in coupling cavity, which was invented by Dr. Xu Zhou (CAEP), and would weaken the E_r field's intensity relatively and enhance the focusing effect of electron beam, meanwhile could restrain the EM field in cavity and depress the coupling coefficient between accelerating cavity and coupling cavity. Fig.3 is the accelerating structure. Fig.4 is the actual cavity. Fig.5 is the result field calculation of the structure using SuperFish7.08. Fig.6 and Fig. 7 is the result of beam dynamics calculation using GPT, which showed that electron beam transverse size is less 1.5mm.

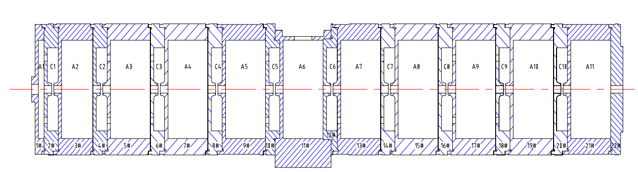


Figure 3: New RF accelerating structure.

Figure 4: Actual accelerating cavity.

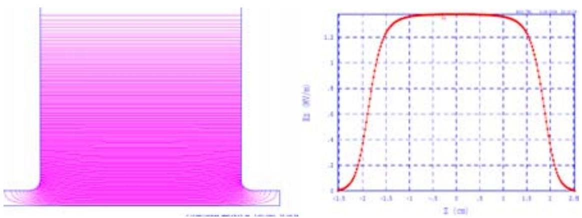


Figure 5: The field distributing of new structure.

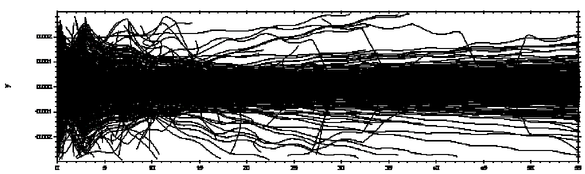


Figure 6: The track of electron beam in new type accelerating structure.

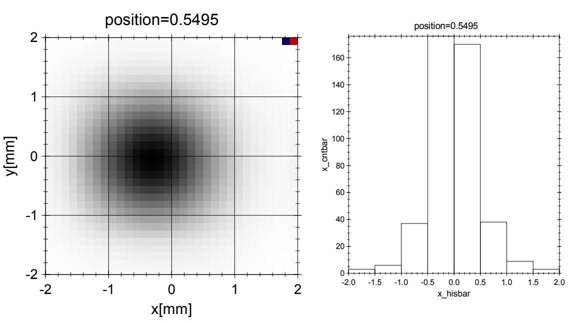


Figure 7: The theoretical calculation result of electron spot.

THE MAIN PARAMETERS MEASUREMENT OF NEW SW LINAC

After the tuning and jointing of the cavities, the main character parameters of accelerator is the following:

The vacuum degree of the fully sealed accelerator is less $5\times10^{-6}Pa$, the high voltage of titanium pump is 4kV, and the current of the titanium pump is less 6μA. The filament of electron gun: 2.2A, 8.2V. On the condition of repetition frequency 50Hz, the pulse width is 4 μs, the emitting property of electron gun is the following

Anode high voltage	23.5kV	26.5kV	28.5kV
Emitting current of electron gun	120μA	140μA	160μA

The flux of cooling water is more 6ℓ/min.

The whole CT/DR system employ klystron (TH2163) as the microwave source, Fig.8 showed the waveform of the microwave coupling (200Hz).

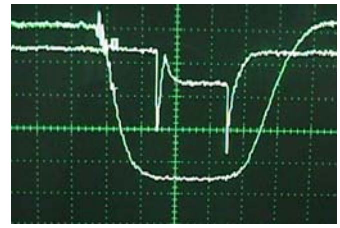


Figure 8: The waveform of microwave coupling (repetition frequency 200Hz).

The radiant intensity at 1 meters away from the target

We use PTW general dosage meter made in German to measure the radiant intensity (dose rate) at 1 meters away from the target, showed in Table 1 and Table 2.

The modulator output voltage is 138 kV, output microwave power 5.5 MW, pulse width 5μs.

Table 1: (Repetition frequency 100Hz)

Distance to Target (m)	1	2	3	4
Radiant intensity(R/s)	33.25	8.3	3.78	2.16

Table 2: (Distance to target 1m)

Repetition frequency(Hz)	68	100	150	170
Radiant intensity(R/s)	22.33	33.9	45.6	50

The measurement of electron beam spot size

The measurement of electron beam spot size is important, totally we use 3 methods to measure the size, here we only provide the measurement result using MTF(by slot) method. Fig.9 is the MTF of flat source-slot imaging system.

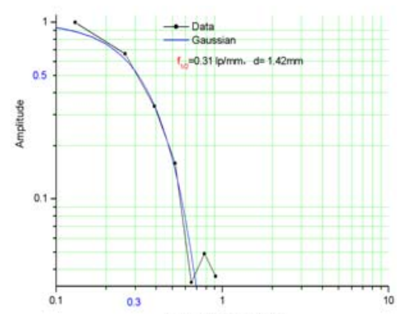


Figure 9: MTF of flat source (slot imaging system).

The FWHM (electron beam size) is calculated by the formula 2, the result is 1.42mm.

$$FWHM_{GS} = \frac{2\ln(2)}{\pi f_{1/2}} \qquad (2)$$

THE TEST OF CT/DR IMAGING

Based on the new type high energy X source, we developed CT/DR integrated test imaging system. Fig.10 is the view of the imaging system.

Figure 10: CT/DR imaging system.

Fig.11 is the CT slice image of resolution plate by our CT/DR system, and Fig.12 is the DR image of the plate. Fig.13 is the titanium pump's DR and CT image. (using LFOV technology).

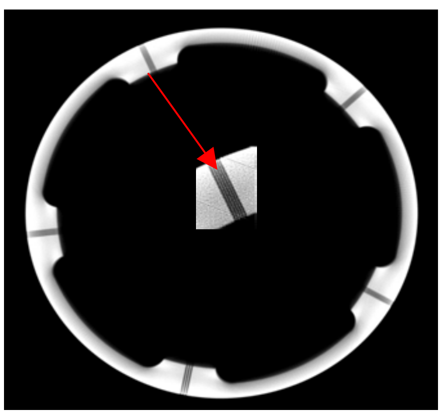


Figure 11: Resolution plate's CT image (2048×2048).

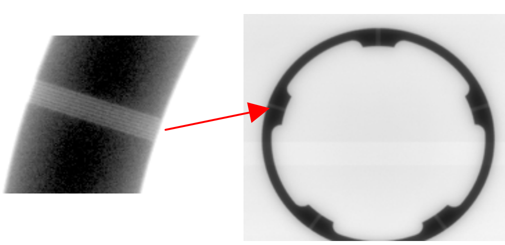


Figure 12: DR image of the plate.

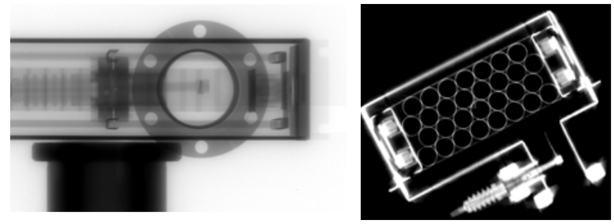


Figure13: Titanium pump's DR and CT image.

CONCLUSION

For reducing the electron beam traverse size, we design a new type RF accelerator, and the spot size is less 1.5mm, the radiant intensity at 1 meters away from the target reaches 33.25 R/s (repetition frequency 100Hz). We developed high energy CT/DR integrated test imaging system using this new type accelerator.

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