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Design of Beam Diagnostic System based on Secondary Electron Emission for Neutral Beam Injector at CRAFT

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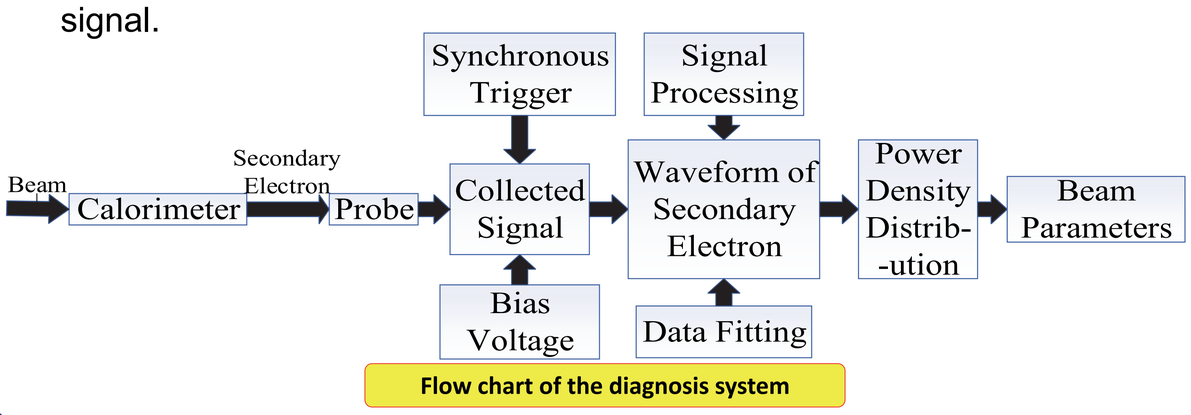
Introduction

- As a reliable heating method with the clearest physical mechanism in the auxiliary heating of magnetic confinement fusion device so far, the Neutral Beam Injection (NBI) system is essential for the Comprehensive Research Facility for Fusion Technology (CRAFT).
- The beam diagnostic system based on thermocouple can not support some requirements such as the beam density at horizontal direction or the real-time diagnostic for CRAFT negative neutral beam injector.
- To satisfied the requirement of beam diagnostic system, a beam diagnostic system based on secondary electron emission(SEE) for Neutral Beam Injector at the test platform is designed.
- The feasibility of diagnostic system will be verified with some influence factors for secondary electron emission by the finite element analysis.
- Some design schemes about the probes will be given to promote the research at test platform.

Flow chart of the diagnosis system

- Secondary electrons will emission as a result of the calorimeter tubes bombarding by the neutral beam.
- A set of probes will be installed on the calorimeter, which can collect the secondary electrons by electrostatic field.
- Beam parameters will obtain by data processing and analysis of probe signal.



Flow chart of the diagnosis system

The feasibility of diagnostic system

- Some of the curves about secondary electron yield(SEY) is giving by the result of theoretical calculation.
- The curves of SEY which is obtained by the finite element analysis are consistent with the result of theoretical calculation base on formula.

Some curves of SEY

theorization about SEY

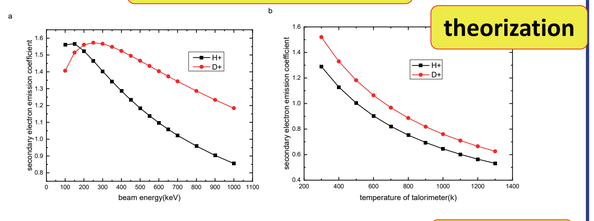
$$Ye(E) = \int_0^Z \int_0^E \Phi(x,E)\Delta e(x,E)dxdE$$

$$Ye(E) = \int_0^Z \int_0^E 0.5\Phi(x,E)\frac{1}{E_0}\Gamma A L_s[1+F(v_i)]\frac{1}{cos(\theta)}\left(\frac{dE}{dx}\right)dx$$

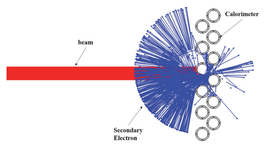
$$Ye(E) = \int_0^Z \int_0^E \Phi(x,E)\Delta e(x,E)dxdE = f(\Phi_n)\Delta$$

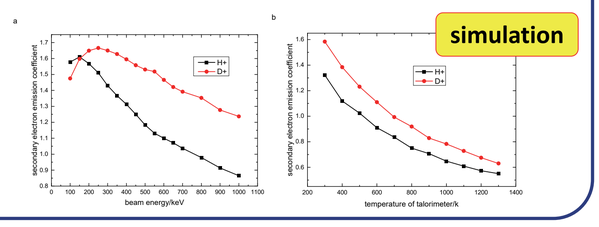
$$\Gamma = 1 - \left[\frac{\Phi_D}{E_s+\Phi_D}\right]^{0.5}$$

$$F(v_i) = 1/(1+\frac{L_\delta}{L_s})$$



Model about SEE

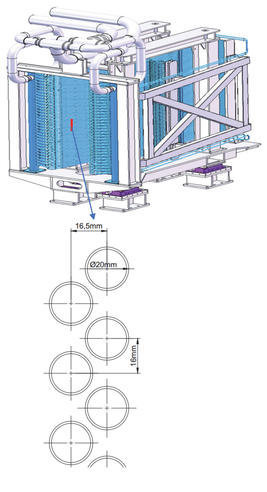




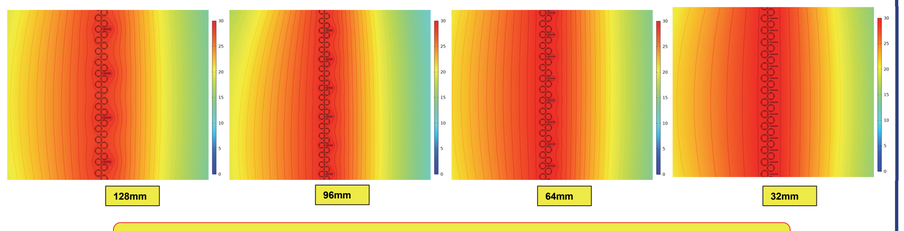
Modeling simulation of probe position

- The position of the probe directly affects the electrostatic field configuration formed by the probe.
- In order to reduce the interference between different probes and adapt to the calorimeter, the adjacent probes are about 128mm apart.
- The distance form probe to tube will be about 1mm to get the best attraction electrostatic.

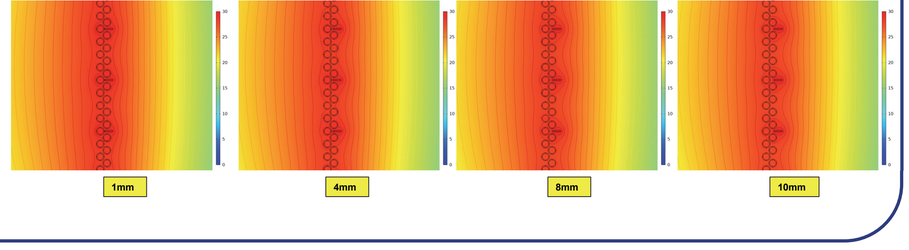
Calorimeter of NNBI



Electrostatic filed with different distance from each probe

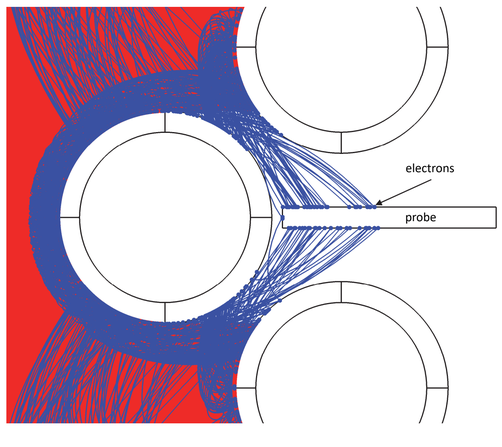


Electrostatic filed with different distance from probe to tube

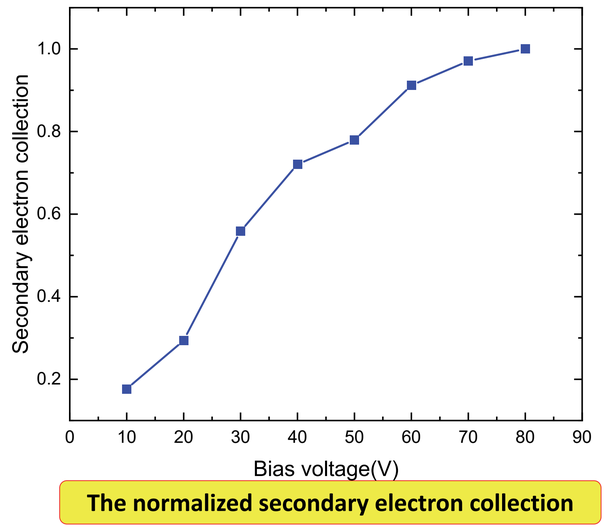


Modeling simulation of bias voltage

- Difference from bias voltage has a significant effect on the electron attraction, on the other hand, most of the electrons are come from the nearby two tubes.
- Result form modeling simulation has given the secondary electron collection with different bias voltage.



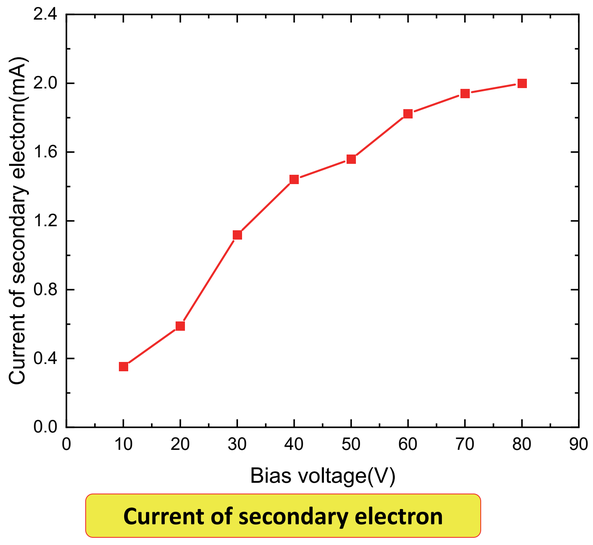
Electrons from the tubes to probe



The normalized secondary electron collection

Expectation of electrical signal and the signal processing

- The bias voltage could be around 50V to gather the secondary electron and the expectation for current of each probe with secondary electrons is 1-2mA approximately.
- To collect and process the electrical signal, decided to use a sampling resister to convent current into voltage for the signal processing, the signal processing system has been preliminary completed.



Current of secondary electron

Preliminary signal processing system

Conclusions and future works

- **A flow chart of the diagnosis system has been given and the feasibility of the system is verified by finite element analysis.**
- **Probe positions and bias voltage of probes has been given with modeling simulation using finite element analysis.**
- **Each probe would gather about 1-2mA based on the modeling simulation so that the preliminary plan is using a resistance circuit to convent current into voltage for the signal processing.**
- **The next step is to improve the model to ensure the reliability of simulation, such as the influence of plasma potentials and the global electric field distribution in space.**
- **Experimental measurement will be carried out in test platform to confirmed the practicability of the diagnosis system in the future.**

Acknowledges

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