An accelerator-based in-situ surface diagnostic for plasma-wall interactions science on Alcator C-Mod

Principles of *in-situ* ion beam analysis

1. **Radiofrequency quadrupole linear acceleration** - Beam is injected into the vacuum vessel through a radial port.
2. **Toroidal and vertical magnetic fields** - In the target area, the magnetic fields (B) electrostatically steer the charged ions to the PFC surfaces.
3. **D+ ions hit specific nuclear reactions** - The ions produce neutrons and gammas in specific nuclear reactions.
4. **In-situ detection and energy spectroscopy** - Gamma rays and neutrons produced in the target area are detected and their energy spectra are measured.

A beam dynamics code calculates deuteron trajectories for magnetic requirements and PFC accessibility.

**Example: in-situ surface diagnosis of boron thickness in C-MOD**

- **Alcator C-MOD conditions** - The diagnostic is performed under the same conditions as those on the plasma-facing components (PFCs).
- **time evolution in response to plasma conditions** - The diagnostic is performed in real-time, allowing for the evolution of PFCs.

**ACRONYM**

- **B(d,p+g) reaction** - This reaction gives a gamma from the production of tritium and gamma rays.
- **B(d,p+g) reaction, 0.95 MeV peak** - This peak is used to determine the boron thickness.
- **custom-built photodiode** - A silicon avalanche photodiode (SiAPD) is used to detect the gamma rays.
- **custom-built electronics** - These include a custom-built photomultiplier tube (PMT) and a custom-built high voltage supply.
- **Data acquisition system (DAQ)** - This includes a custom-built fast waveform digitizer and a custom-built server/RAID computer.
- **fast waveform digitizer** - The digitizer is housed in aluminum for optical readout and features a custom-built detector.
- **FPGA firmware** - The firmware consists of custom-built electronics and data storage.

**Overview of the diagnostic**

- **Boundary science in magnetic confinement devices** - This field is hindered by the lack of PFC diagnostic techniques.
- **significant challenges for long-pulse or steady-state magnetic fusion devices.** - This results in the development of novel diagnostic techniques.

**Plasma-material interaction science**

- **Plasma-material interaction science** - This field requires a deep understanding of the interactions between plasma and materials.
- **beam spectroscopy provides quantitative PFC surface analysis** - This technique allows for the analysis of PFC surfaces under plasma conditions.

**A Monte Carlo synthetic diagnostic has guided diagnostic development and will aid in data interpretation**

**Data acquisition system (DAQ)**

- **The DAQ consists of fast waveform digitizers** - Various digitizers are used to record data from different PFCs.
- **The DAQ includes a server/RAID computer** - This computer is used to store all data from the diagnostic.
- **The DAQ is supported by U.S. DOE Grant DE-FG02-04ER54425** - This grant provides funding for the development of the diagnostic.

**Assembly of the diagnostic has begun:** Diagnostic beamline into C-MOD is complete.

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