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Design, performance and construction of a 2 MW ion beam test facility for plasma facing components

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Abstract

A new facility for the testing of plasma facing components (PFC) under high heat fluxes is presently under construction at IPP Garching. The aim of this facility is to provide thermal testing capabilities for high heat loaded divertor components which have both active water cooling and large outer dimensions. The water-cooled test chamber is equipped with two ion sources for positive ion beam production. Initially, only one of the two individually controlled RF ion sources with 1.1 MW maximum beam power will be used for heat loading tests within an operating regime from 5 to 65 MW/m^2 at the target position. This paper presents the details of the technical characteristics and the systems for vacuum generation, cooling, power supply, control, target diagnostics and data acquisition.

Keywords: High heat flux test facility; Ion beam; Plasma facing components; W7-X

1. Introduction

The investigation of the thermo-mechanical behaviour of actively cooled plasma facing components (PFC) for the next generation of long pulse fusion experiments requires extensive thermal tests with heat loads similar to the operational conditions. Especially, the quality control and acceptance tests of industrial manufactured divertor components for Wendelstein 7-X and ITER need the support of powerful high heat flux (HHF) test facilities.

Additional to the existing HHF test facilities, e.g. [1–6], the IPP Garching is building a HHF test facility on the basis of available ion sources and power supplies from the decommissioned W7-AS stellarator. The experiences of IPP in the development and operation of neutral beam injection systems will ensure the successful adaptation of existing ion sources to the requirements of the material test facility. For the long pulse operation of existing ion sources and the requirement of a high duty cycle in full power operation, demands they be upgraded. Regarding the testing of large HHF loaded components, this requires an increase

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of the pulse length up to 15–30 s for maximal beam power.

Heat load tests of W7-X divertor target plates, which are in production [7], are the main activities planned for the next years. These tests are essential to ensure the successful development, manufacturing and operation of these components. In addition to the thermal tests of single target elements, completely mounted target modules (10 different types) will also be thermally tested in the facility. The examination of their operational behaviour (e.g. thermal response, heat removal capability depending on cooling water velocity and surface temperature distribution as function of incident heat flux) is an important contribution to a successful start of plasma operation in W7-X.

Initially, only one of the two installed ion sources will be used for heat load tests in an operating regime between 5 and 65 MW/m^2 of power density at target position.

2. Facility design

2.1. General description

The main components of the facility, the arrangement of the ion sources and the test chamber are shown in Fig. 1. The current design includes the possibility of future operation with two individually controlled ion beams. Table 1 summarises the technical characteristics of the test facility. Both ion sources are inclined at 8° to the horizontal axis of the facility. The beam cross-over at 3 m distance from the extraction grid will be the target position in section II. This arrangement allows an alternating operation of ion sources during test campaigns allowing for maintenance or improvement, respectively. In a future upgrade, it will be possible to superpose the two individually controlled ion beams for testing of large scale divertor components.

Table 1
Technical characteristics of the IPP high heat flux test facility

Maximum power of the beam	1100 (2200) kW
Maximum acceleration voltage	55 kV
Maximum current	20 A
Heat flux density: beam centre	5–65 MW/m^2
Pulse duration	1 ms–15 s (30 s)
Number of cycles/h	~100
Beam spot, 80% of central density	≥70 mm
Component layout	Horizontal/vertical
Heated length of component	200–700 mm
Maximum length of test sample (inclined)	2000 mm
Maximum cooling water temperature	80 (150) °C
Maximum water pressure	25 (45) bar
Water flow rate	0.5–8.5 (>9) l/s

Brackets mark values with the potential for upgrading.

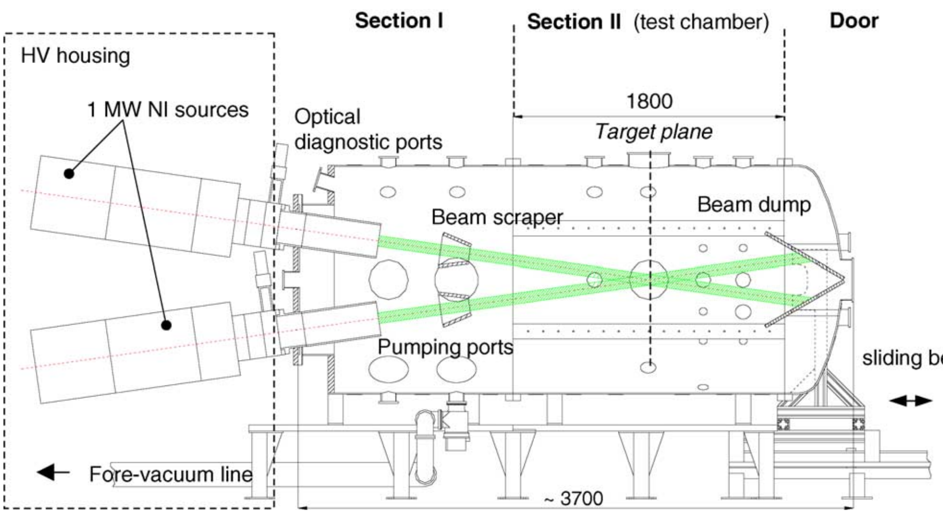

Fig. 1. Cross-section of the HHF test facility. The total length of the device is about 6 m.