stellarator news

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Topping-out ceremony of the new buildings of the IPP Greifswald Branch

The topping-out ceremony for the new buildings of the Max-Planck-Institut für Plasmaphysik Greifswald Branch took place on 24 August 1998 in the presence of the builders, the future users, and many guests coming from all over Germany. They were joined by Dr. Jürgen Rüttgers, the Secretary of State for Research, Science, Education and Technology; Dr. Bernd Seite, the President of the Cabinet Council of the federal state of Mecklenburg-Vorpommern; Regine Marquardt, the Minister of Culture and Education; representatives of the European Union, and members of the Hanseatic town and of the University of Greifswald.

After the laying of the foundation stone in June 1997, the building operations commenced, and the concrete structure of the experimental hall and of the office block is now completed. The work started with the experimental hall for the Wendelstein 7-X device, which has now reached its final height of 25 m. A wave-like roof, to be constructed by November, will connect the hall to the central building and to the three office wings. Also, it is planned to finish the masonry of the neighboring technical buildings by the same time.

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Fig. 1. Aerial view of the building site at Greifswald at the end of August 1998.

About 300 staff will work in the IPP Greifswald Branch Institute. Including those who are still working in Garching and Berlin, 105 positions are currently occupied. At present 21 persons work in Greifswald in rented offices. They belong to the Standortentwicklung Division, which is responsible for the erection of the buildings (head: Prof. Grieger) and to the Stellarator Theory Division (head: Prof. Nührenberg). The Wendelstein 7-X Construction Division (head: Dr. Wanner), responsible for the design and construction of the experiment, will move from the Garching site to Greifswald in March 1999. Cooperation with the Physics Department of the University of Greifswald started in 1996/97 with lectures from IPP scientists.

Building the Greifswald Branch Institute (experiment, diagnostics, buildings) will cost 600 million DM. The federal state of Mecklenburg-Vorpommern will provide 120 million DM. One-third of the remaining 480 million DM will be financed from the European Union Fusion Program (for the W7-X device, this fraction will be 45%); the remaining two-thirds will be paid by the Federal Republic and the state of Mecklenburg-Vorpommern in the ratio 9:1, as is customary for German national laboratories. The buildings are expected to be finished by the year 2000. The start of the experimental work is scheduled for 2005.

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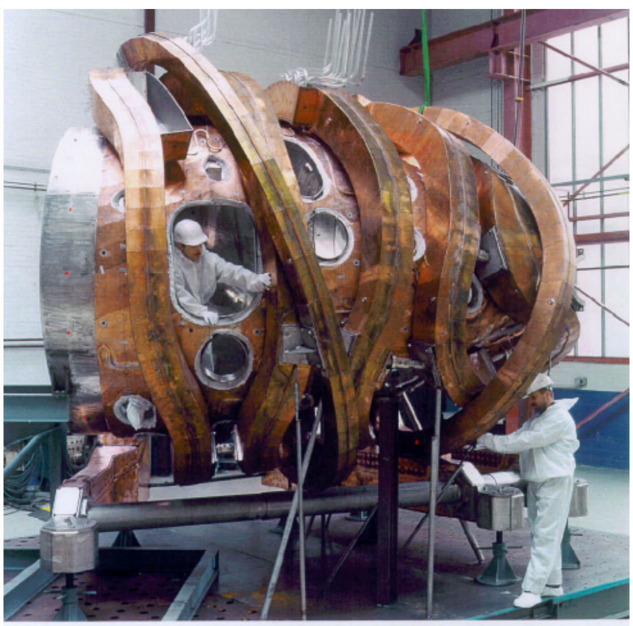

Fig. 1. The "inner part" of the W7-X demonstration cryostat: plasma vessel sector with port holes and 80 K shield, nonplanar and planar coil mock-ups and support structure (photo: Balcke-Dürr).

W7-X demonstration cryostat close to completion

One of the tasks of the R&D program for the Wendelstein 7-X (W7-X) stellarator experiment is to construct a full-scale cryostat sector. It comprises the plasma and outer vessel sectors including a module separation flange, 6 nonplanar and 2 planar coil mock-ups with conductor joint models, the coil support structure, 24 plasma vessel ports, and thermal as well as electrical insulation. The plasma vessel and ports are suited for ultrahigh-vacuum operation, and the coil mock-ups and support structure are designed for cool-down to 4 K.

Balcke-Dürr Company in Ratingen, Germany, was entrusted with the challenging task of building the demonstration cryostat; the cryo-technical part was taken over by Linde Company, Munich, Germany, as subcontractor.

The purpose of this project is to gain experience in design and construction of these novel components, as well as to test assembly methods, cooling, measurement, and insulation techniques. Further aims are to deal with critical technical issues at a preliminary state and to demonstrate the availability of the technology for W7-X.

With the exception of the coil mock-ups, all components fulfil the functional requirements of W7-X. The hollow coil models are geometrically identical to the real superconducting coils, including the housing cooling channels and conductor terminals. The latter as well as the conductor joints are electrically insulated to withstand 12 kV at Paschen minimum conditions. As no current operation is foreseen, the coils and support structure are of a lightweight design. Nevertheless, these components are well suited for assembly and cooling studies.

In contrast to the complete W7-X torus, end covers are necessary for both the plasma and outer cryostat vessels. Both 5 K and additional 80 K radiation shields are installed at these sector ends to allow unambiguous thermal loss measurements which are relevant for the whole torus.

The "inner part" of the demonstration cryostat, as shown in Fig. 1, consists basically of the plasma vessel sector (Fig. 2), the coil mock-ups, and the weight support, as well as the vault structure between the coils. This assembly was finished at Balcke-Dürr and delivered to IPP in July. The outer vessel came in four parts: the upper and lower halves, separated at the horizontal midplane, and the end caps. Presently both outer vessel halves are equipped with multilayer thermal insulation and the 80 K shield. The "inner part" will then be lifted into the lower vessel half. Thereafter the lower ports can be inserted from the outside and welded to the plasma vacuum vessel as well as outer vessel walls. All the inner piping and instrumentation will be completed at this point, and the "domes" of the lower vessel part, containing the corresponding coil cable joints, can be mounted. Then both halves of the outer vessel will be welded together, and the remaining upper ports and domes will be installed. Finally, the sector end shields and vessel caps can be built on. All assembly work is to be finished late this year.

A report on design and construction details is to be given at the 20th Symposium on Fusion Technology (SOFT), September 7–11, 1998, Marseille, France; poster P6-222, "Design and manufacture of the demonstration cryostat for the fusion experiment Wendelstein 7-X," by A. Brenner, H. G. Grobelny, M. Podhorsky (all Balcke-Dürr), F. Schauer, and B. Sombach (IPP).

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Fig. 2. View into the plasma vessel sector of the demonstration cryostat (photo: Balcke-Dürr).

Compact Auburn Torsatron Upgrade for the U.S. stellarator program

The proposed U.S. stellarator program (see *Stellarator News*, issues 57 and 58) highlights two novel stellarator concepts based on the principles of quasiaxisymmetry and quasiomnigeneity. In the quasiaxisymmetric configuration, a significant fraction of the rotational transform is predicted to be generated by the bootstrap current. As exemplified by the National Compact Stellarator Experiment (NCSX) under design at Princeton Plasma Physics Laboratory, as much as 50–80% of the requisite rotational transform $\iota(a) \sim 0.4$ is to be supplied by internal current. With the plasma current, there exists the possibility of current-driven instabilities and disruptions in this class of compact stellarators. The conditions under which disruptions occur and the severity of disruptions in current-carrying stellarator plasmas will be investigated on the Compact Auburn Torsatron (CAT), which will be upgraded for this purpose to contribute to the future proof-of-principle scale experiments of the U.S. program.

Disruptions in ohmically heated stellarators have been investigated both theoretically [1–3] and experimentally [4,5]. Experimentally, disruptions are suppressed in $\ell = 2$ stellarators (relatively flat external rotational transform profile) with peaked ohmic current profiles when the external transform is $\iota = 0.14$. The observed reduction of instabilities is generally consistent with linear tearing mode theory. To investigate current stability in a broader range of stellarator configurations, including those similar to the devices proposed for the U.S. compact stellarator program, new MHD instability and disruption studies are planned for the Compact Auburn Torsatron, in which the external magnetic shear is moderate and positive (stellarator-like) and the central transform is variable, $\iota(0) = 0.08$–0.6. The experiments will be performed by addition of ohmic current into rf-generated plasmas. Some variation in current profiles can be expected during the finite time of the current penetration into the preformed plasma column.

Upgrade Plans

To carry out these studies, the CAT device will be upgraded in three major steps:

1. Increase of the magnetic field from $B = 0.1$ T to 0.5 T.
2. Implementation of nonresonant ICRF plasma generation with $P_{rf} = 200$ kW.
3. Addition of ohmically driven plasma current ($I_p =$ 25 kA; $\iota_J(a) = 0.5$).

The increased magnetic field in the upgraded CAT device will be provided by 10 motor generators (GE type EB-752)

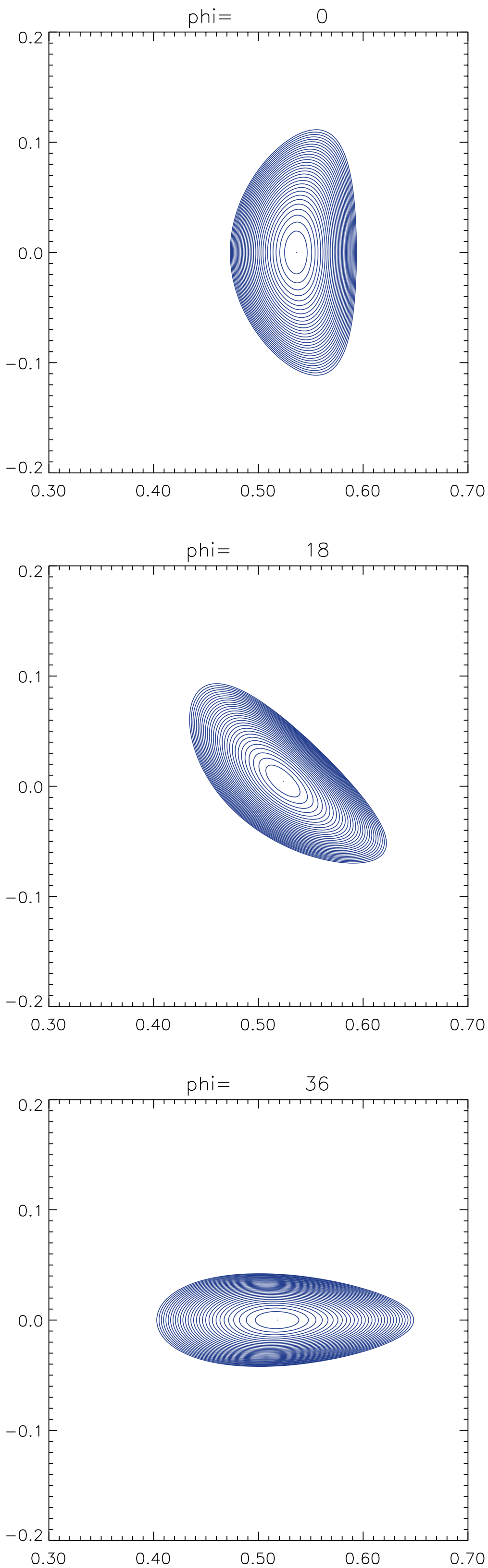

Fig. 1. Flux surface cross sections at toroidal angles $\phi = 0°$, 18°, and 36° (one field period = 72°); $B = 0.5$ T and I_p = 9 kA. The horizontal and vertical scales are in meters.

donated by the Massachusetts Institute of Technology and the University of Wisconsin. Eight are already on site being prepared for operation. The rf amplifiers in the 5 to10-MHz frequency range will be duplicated from plans of similar units on CDX-U. The ohmic transformer to be inserted through the center of CAT will be powered by capacitor banks, and an electrical break must be cut into the existing vacuum vessel.

The device and plasma parameters of CAT and CAT Upgrade are listed in Table 1. The higher field of the upgraded device and the ICRF power (coupled with a Nagoya Type III antenna) will lead to hotter and denser plasmas ($n_e = 10^{19}$ m^{-3}; T_e = 200 eV) than presently available on CAT, and the substantial rf power will allow the variation of plasma current for stability studies without large changes in the background plasma parameters. The controllable magnetic island size in CAT [6] may be useful for studying the possible effect of static islands on stellarator disruptions.

Stability

The current-carrying plasma equilibrium is modeled with the free boundary code VMEC [7]. In Fig. 1, flux surface cross sections are shown for three toroidal angles within a field period; the plasma current in this example is I_p = 9 kA and the magnetic field is B = 0.5 T. The magnetic axis is nearly circular. The stability to tearing and ideal modes is modeled in simplified cylindrical geometry [1]. The rotational transform profiles and current profiles are shown in Fig. 2 for a case similar to that illustrated in Fig. 1. The external transform is indicated in black, and the total transform with the assumed ohmic current profile (dashed blue line) is shown by the solid blue line. As is common with the ohmic and external transforms being of opposite sign, this profile is predicted to be unstable to tearing modes with mode numbers m/n = 3/2 and 1/2. It is not known if this will lead to a severe disruption, but experience on previous stellarators [8] suggests that it could. Therefore, with sufficient profile measurements, this flexible experiment will increase our understanding of the disruption physics of current-carrying stellarator plasmas.

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Table 1. Parameters of CAT and proposed CAT Upgrade

	CAT	CAT Upgrade
Number of field periods	5	5
Vessel major radius (m)	0.53	0.53
Vessel minor radius (m)	0.17	0.17
Plasma minor radius (m)	0.1 (typ.)	0.1 (typ.)
Magnetic field (T)	0.1	0.5
Density (m^{-3})	7×10^{16}	$0.5–1 \times 10^{19}$
Electron temperature (eV)	10	200
Heating power (kW)	2 (ECH)	200 (ICRF); 50 (OH)
Rotational transform	0.1 – 0.7 (edge)	1 (axis)
Plasma Current (kA)	0	25

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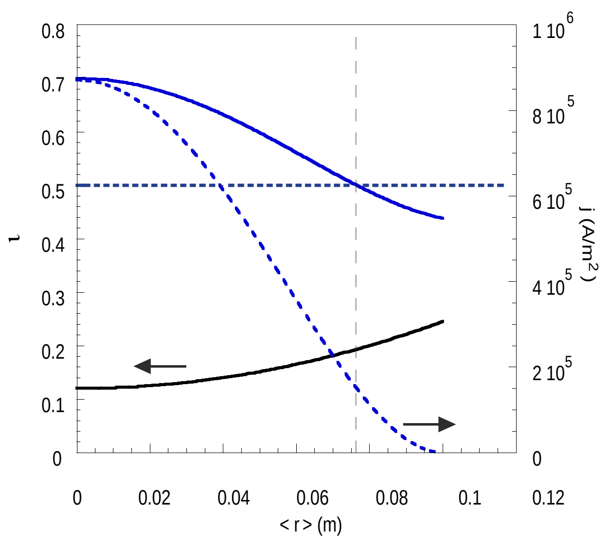

Fig. 2. Rotational transform profiles with and without plasma current of I_p = 9 kA (solid blue and black lines), and plasma current profile (dashed blue line). Cross-hairs indicate location of ι = 0.5 surface, which is unstable to tearing modes.