Det Naturvidenskabelige Fakultet,

Københavns Universitet.

Ørsted Laboratoriet, July 1, 2002

Re: Nils Basse's Ph. D. thesis

We enclose our evaluation of Nils Basse's written thesis. The oral presentation of his work was fully satisfactory, and we therefore recommend to the faculty that he obtain the Ph. D. degree.

Yours Sincerely

Mogens Høgh Jensen Dominique Gresillon Jens Juul Rasmussen

Report on the thesis document entitled :

Turbulence in Wendelstein 7-AS plasmas measured by collective light scattering

by **Nils Plesner BASSE**

(in partial fulfillment of the requirements for the PhD degree of the Niels Bohr Institute for Astronomy, Physics and Geophysics, Copenhagen, Denmark.)

The thesis is devoted to experimental investigations of density fluctuations in the core region of magnetically confined plasmas. The investigations are performed at the Wendelstein 7-AS stellarator device at IPP Garching, Germany. The studies are based on measurements of collective scattering of laser light from the density fluctuations in the central plasma region, using the LOTUS system developed and built at Risø, Denmark.

The thesis is divided into two main parts: Part one describes the background theory for collective scattering and the data analysis. Part two starts with a short summary of the theory behind plasma fluctuations and transport, and introduces important definitions of the different mechanisms. The major part is devoted to a description of the experimental set-up, the measurements, and the evaluation of the results.

Fluctuations of large amplitude have long been suspected to play an important role in the so-called plasma "anomalous transport" out of the confinement topology in magnetized plasma devices. The purpose of the present thesis is to investigate density fluctuations in the "Wendelstein 7-AS" stellarator, by means of the "collective scattering" diagnostic, for different plasma regimes and in correlation with other plasma observations. With this objective, the present work collects, in a very methodical way, different techniques and knowledge, and leads all of them to valuable achievements. The author has collected a very impressive bibliography (amounting to 178 references) on collective scattering devices and observations. He also made a resume of the different instabilities which develop in these plasmas, and of their contributions to the experimentally known and typified plasma behaviours.

The key device in the thesis is the new collective scattering diagnostic bench "LOTUS", built by the Risø team in Denmark to be installed on the Wendelstein 7-AS plasma machine. LOTUS is a very elaborate device, able to observe scattering in various clever ways. LOTUS is one of the most sophisticated far-infrared optical benches presently operated. Using most of the classical techniques (gaussian beam optics, super-heterodyne detection) it adds an impressive number of optical elements (no less than 17 lenses, 18 mirrors) together with not-so common elements like dove prisms to change the scattering plane. A large amount of time must have been spent to design, build and align all of these optical components. One of the new features of this bench, with respect to its ancestors, is the double scattering volumes and signals. This feature, when combined with a crosscorrelation analysis, was designed to compensate for one of the collective scattering drawbacks, that is the lack of information on the signal source localization along the optical beams. Such information was obtained in the experimental campaign by this method (see Figs. 8.50 and 8.58, 8.59). It could have been obtained, and indeed it was also obtained in this thesis (Fig. 8.51), by the simpler method of a single channel with a sharply defined scattering wave vector.

Two operating regimes are known in present days tokamak as well as stellarator fusion devices: the L (low) and H (high) confinement regimes. Most of Nils Basse's observations are devoted to characterize the differences in the plasma density fluctuations, and localization, in these two regimes. New and detailed observations are clearly presented. Especially spectacular are the 3D time-frequency spectra (color coded) in Figs. 8.12, 8.62, 8.68, where the L and H spectra are clearly shown as well as the transition periods. Among the density fluctuation features that were discovered in this thesis, it is worth to note: The form factor variation with wave vector (Figs. 8.14 and 8.20) seems indicative of a continuous dissipative range of scale, unless it shows a "production range" at a specific scale. This is clearly shown in the thesis. It will certainly be appealing for further investigations. The absolute correlations of density fluctuations (in different frequency bands) with H-alpha radiation and with Mirnov coil rms fluctuations are very detailed and significant. Most of Nils Basse's observations are firmly and clearly established. They will provide references for improving confinement understanding.

The thesis is impressive in the synthesis it presents on preceding knowledge, in the amount of work it involves, in the significance of its finding, as well as in its building, content and clarity. The obtained results are at a high international scientific level and the thesis fully satisfies the requirement for a PhD degree.

July 1 2002

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