I.T.E.R.

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Abstrakt:

Fusion energie research has come to a stage at which the newly designed International Thermonuclear Experimental Reactor (ITER) can be build - a machine which will demonstrate the feasibility of generatinga significant surplus of energy with a thermonuclear plasma

1 Úvod

For the first time in history scientists have a complete design for a machine which will deliverenergy from controlled thermo-nuclear reactions under quasi-stationary conditions – the International Thermonuclear Experimental Reactor (ITER). This machine will deliver 10times more energy than is needed to generate the high emperature conditions required to maintain plasmas at more than a 100 Million degrees C.Research has come a long way and a variety of concepts for the generation and confinement of such high temperature plasmas has been proposed. Many different roads have been tried, some are still promising, but one road seems most successful:he tokamak line as represented by the largest device in the world the Joint European Torus and its larger brother the next step device.After about two decades of research in modertokamaks of different size and shape a data base has now been assembled, which permits a reliable design for ITER and which makes scientists confident about the main goal: the generation of a burning fusion plasma as a proof of principle for a fusion reactor.There is no longer a problem with reaching the high temperatures T at which the thermonuclear reactions start. Neither the high densities n required nor a plasma pressure of about 1 bar seem to be a problem, nor does reaching a sufficiently high energy confinement time $\tau = E/$ Pheat,where E is the energy content of the plasma and Pheat the total heating power to theplasma. τ is a measure of the heat insulation of the whole plasma. Only with sufficientlyhigh τ the break even point, where Pfus the fusion power generated equals the external.

2 A new primary energie source

Among the possible fusion reactions the highest rate is given by the binding of the hydrogen sotopes Deuterium and Tritium to Helium

$$D + T \rightarrow He4 + n .$$

The nuclear binding energy between the nuclei of Helium (alpha-particle) is higher than the sum of the binding energies of D and T yielding a difference of 17.6 MeV or 2.8 10-12 J. This free energy is distributed among the alpha-particle (3.5 MeV) and theremaining neutron.

The isotope Deuterium is found in natural Hydrogen with an abundance of 1:6000 and can be easily extracted e.g. from water. Since Tritium is unstable decaying with a half life time of 12 years it has to be generated in a nuclear reaction. The neutron produced in the fusion reaction serves for this purpose. It can breed Tritium from Lithium in a so called breeder blanket surrounding the fusion plasma chamber and finally JET produced in 1997 in a 50:50 mixture Deuterium-Tritium the record value of 16 MW of fusion power at Q=0.6 (Q=0.9 after correction for rising energy content). This is an important milestone in fusion research providing a proof of principle to those who were suspicions what controlled thermonuclear fusion works at all. It is also a major milestone for fusion technology demonstrating a safe operation with a full tritium cycle including tritium storage, injection, recycling and removal. For the plasma scientists the fusion power output was not such a big surprise, since they could already calculate from previous experiments in Deuterium what fusion power is to be expected. There even cases exist with Q somewhat beyond Break Even.Unknown was the effect of alpha-particle heating on plasma stability. In principle the fast alpha-particles can trigger instabilities which might lead to a deterioration in confinement. The results from JET and TFTR have not indicated further problems in this respect. However, the contribution from alpha-particles to the total plasma heating is still rather small compared to a reactor. With a given energy amplification factor Q the ratio of heating power Pα from alpha-particles to auxiliary power is given by Pα /Paux = Q/5, since Pα is 20% of the total fusion power. For JET with Pfus = 16 MW, Pα= 3.2 MW and Paux = 26 MW this means Pα / Paux = 0.12, whereas for ITER we expect Pfus = 500 MW, Pα = 100 MW and Paux = 50 MW giving Pα / Paux= 2. This difference in alpha-particle heating is one of the major issues to be studied onthe next step device ITERIt should be noted that the steady state results in DToperation may be more relevant than the record value of 16 MW fusion power in JET. The record value has been obtained in a transient phase where the fusion power was ramped up from zero to 16 MW during 1.5 seconds - clearly not a scenario valuablefor a reactor. On the other hand experiments on JET with a somewhat smaller Q-value (0.2) have also been performed in DT under quasi stationary conditions producing 4 MW fusion power over 4 seconds. This is the scenario which is now used for extrapolation to the next step device.

3 Conclucion

With ITER we have now one solution for an energy delivering fusion device with an energy amplification factor of 10. Integration of all necessary elements of a fusion reactor, including the physics of a fusion plasma and the fusion technology, will provide the last step towards the first power plant DEMO, the construction of which could start in about two decades. Additional progress is to be expected from an accompanying programme which has to pursue materials characterisation as well as concept improvements including diagnostics and heating methods. At this stage the long standing question 'does controlled nuclear fusion work ?' has been answered positively in principle. The present changeover into a new era can be characterised by the open question '... and does it work economically ?'. Consequently the in this respekt crucial topics of steady state operation and availability are high on list of ongoing research. In addition to the ITER-like solution, which we already have, we may later obtain other solutions based on alternative confinement schemes, such as the stellarator or the spherical tokamak, with even Berger performance.In spite of the rather high costs of large experiments, like ITER (about 4000 M€ investment costs), the burden to national research budgets is moderate owing to the cost sharing among many partners in this international project..

Reference:

[1]http://www.jet.efda.org/documents/articles/samm.pdf