NINETEENTH FUSION ENERGY CONFERENCE

SESSION OV/3

Monday, 14 October 2002, at 16:20

Chair: V.P. SMIRNOV (Russia)

SESSION OV/3: Magnetic Fusion Overview 3

Paper IAEA-CN94/OV/3-1 (presented by T. Yamanaka)

Discussion

R.J. Goldston: It wasn't completely clear whether you determined the ion temperature from the neutron spectrum widths (both with and without the petawatt beam) or from the magnitude of the yields.

T. Yamanaka: We determined the ion temperature from the spectral width of the neutron energy since the obtained spectrum agreed well with the Gaussian profile. If you assume the emission time of the neutrons is so short, the energy spectrum of the thermonuclear reactions becomes Gaussian if you measure the energy spectrum using the time of flight method at a distant point. In this particular case the spectral width is 90±5 keV, which corresponds to the ion temperature of 0.8±1 keV. The spectral width without heating is about 50–60 keV and it corresponds to 0.3–0.4 keV for D–D reaction plasmas.

Paper IAEA-CN94/OV/3-2 (presented by J.D. Sethian)

Discussion

R.E.J.G. Koch: How long will the chamber windows through which you shoot the laser beams survive the blasts?

J.D. Sethian: There are no windows on the chamber. The only optics to directly see the blasts from the target are grazing incidence mirrors. These are located 20 meters from the target.

K. Kasuya: What is the best material for the final optics (or mirrors)? What is the shortest distance of the final optics from the target chamber?

J.D. Sethian: So far, aluminum is the best choice of material, due to its high reflectivity, resistance to damage from laser light, and well established material properties. As for the second question, 20 meters.

W.M. Nevins: I was pleasantly surprised at the target cost estimate of US $0.16 each. How does that break down between materials, manufacturing, and quality control?

J.D. Sethian: The cost study includes the following: plant, equipment, material, labor, quality control, land costs, depreciation, support services, etc.

H. Bindslev: How is the drive laser beam zoomed on the short timescale of the target implosion?

J.D. Sethian: In a KrF laser, the laser spot size on the target is determined by an optical aperture at the low energy front end of the laser. By incorporating a Pockels cell switched “optical switchyard” the light in the front end can be diverted through apertures of decreasing size.

Paper IAEA-CN94/OV/3-3 (presented by J. Tassart)

Discussion

D. Meyerhofer: Did you use fill tubes for cryogenic target studies? Will you use fill tubes for ignition targets? How different will the layering be?

J. Tassart: We use fill tubes for the experiments of smoothing and redistribution to optimize the thermal path and IR illumination. For the LMJ cryotarget the microshell will be filled at room temperature by permeation and then cooled to 20 K. It is known today that the crystallization process will be different with and without fill tubes because of cold points, which are germs of nucleation of the solid DT layer. We have not yet made experiments on microshells filled by permeation but it would be possible (in our opinion) to tailor a cold point to obtain DT ice layers with low roughnesses.

R.J. Goldston: In your list of concerns you did not include Rayleigh–Taylor instability of the inner surface of the compressed fuel as it decelerates against the low density hot spot. Can you explain the experimental evidence that now exists on the integrity of this interface?

J. Tassart: I have not listed the unstable interfaces during the implosions. I only globally pointed out the growth of hydrodynamic instabilities as a major risk of shell breaking or hot spot extinction. It is well known that instability growth analysis during capsule implosion is quite complicated due to the propagation of several shocks reflected on several interfaces. Indeed the perturbation growth and propagation from the inner surface is a concern. The campaign of “feed-through” experiments on Omega at Rochester is aimed precisely at that question. I showed a picture of the device and first, preliminary, unresolved data. A lot of work is still necessary to fully understand these data and then to go beyond planar geometries towards the actual spherical one.

Paper IAEA-CN94/OV/3-4 (presented by B.G. Logan)

Discussion

K. Kasuya: Different species were chosen for the injector experiments, the transport research and numerical simulations, namely Ar, K and Xe. What was or were the reason(s) that you chose these species?

B.G. Logan: We use an existing K^+ contact ionization source for the transport experiment to save cost. The injector experiment with a multi-beamlet extraction geometry uses a plasma Ar^{+1} source because it is easier to feed one plasma source into many extraction holes. We simulate Xe^{+1} ions because heavier ions are optimum for reactor cases, but we also simulate the K^+ and Ar^+ ion beams for the transport and injector experiments.

Paper IAEA-CN94/OV/3-5 (presented by M.H. Key)

Discussion

K. Mima: Do you think that proton driven fast ignition is feasible from the standpoint of a fusion power plant? What is the expected efficiency? Please describe the laser pulse shape and intensity. How much laser energy is required?

M.H. Key: The proton approach is new and relatively little investigated. It is too early to say if it is feasible. It is interesting because it avoids the complexities of relativistic electron transport and initial work has been encouraging. Some of this work (Snavely et al., Phys. Rev. **85**, 2945 (2000)) showed very good efficiency of converting 400 J, 0.5 ps pulses to protons (12% at energies >10 MeV implying quite high integrated efficiency assuming the observed exponential spectrum is extrapolated with the same exponent slope to energies below 10 MeV). For full scale fast ignition the energy required in the ignition spot from the proton beam is similar to that for electrons (Temporal et al., Phys. Plasmas **9**, 3102 (2002)) and therefore of the order of 30 kJ. The required laser energy depends on the conversion efficiency and focal spot size of the proton beam. It is likely to be of the order of 100 kJ and laser technology constraints will therefore suggest using the maximum permitted pulse length of 20 ps. We do not yet know how the encouraging conversion efficiency and focusability of the protons observed with the current shorter pulse and lower energy will extrapolate to FI conditions. Factors to be concerned about for longer pulses at similar intensities include possible loss of conversion efficiency and focusability and closure of the vacuum gap, for proton generation.

R.J. Goldston: It seems to me that it must take at least six years to construct an ETF. Your diagram therefore implies you would propose starting construction of the ETF in advance of having ignition or results from an IRE. Do you mean to be saying this?

M.H. Key: Extrapolating the FI plan to an ETF is very speculative. The big question I think is whether and when the FI concept should transition from concept exploration to more substantial proof of principle studies and what would be done in the proof of principle phase. This near to mid-term phase can be taken seriously — beyond that the plan is increasingly speculative. The ETF phase must include design and construction, which would not be undertaken without convincing ignition results and IRE of technology demonstrations.

V.P. Smirnov: Converging laser pulse energy to a proton beam should lead to a spread of pulse duration. How will this change the ignition condition?

M.H. Key: The amount of transit time spread for protons of different energies depends on the distance between the source and the FI hot spot. This pushes designs towards values of this distance of 1 mm or less in order to minimize the ignition energy. The problem has been analyzed by Temporal et al., Phys. Plasmas **9**, 3102 (2002), and it is seen that the fastest protons arriving first heat the plasma. This increases the proton range, and allows later arriving slower protons (with insufficient range in cold plasma) to penetrate the necessary 0.5 g cm^{-2}. The result is a reduction in the required mean energy of a typical exponential energy spectrum to an already demonstrated value of 4 to 5 MeV. This model result provides an encouraging reduction in requirements.