As for the cone heating, it is expected that the laser light is concentrated into the tip of the cone by laser interference. Relativistic electrons are then generated by intense laser fields and guided into the top of the cone [7]. In the experiment shown in Fig. 3, the fast heating of the compressed core raised the temperature from 0.4 keV without heating to 0.8–1 keV at about 0.5 PW heating. As a result, the fusion neutron yield increased by three orders of magnitude. More importantly, the neutron yield data indicate that a sizable fraction of 20-30% of the laser energy is converted to the thermal energy of the core.

**FIREX PROJECT**

The consequent milestone is obviously to demonstrate ignition and burn. The program to achieve this milestone is named as Fast Ignition Realization Experiment (FIREX). In order for the program to be flexible, it is divided into two phases: The goal of the first phase is to demonstrate the ignition temperature of 5-10 keV by a high-energy peta-watt (10kJ/10ps) laser [8]. This is followed by the second phase to demonstrate ignition and burn.

Since the burning wave travels through the entire fuel at a velocity much faster than any other hydrodynamic velocity, the burning proceeds no matter what the fuel size is. The energy gain increases simply with increasing the size of the compressed core. Indeed, our two-dimensional hydro-code simulation predicts that energy gain increases monotonically from 5-10 at FIREX to more than 100 at reactors. There is no essential difference between the FIREX-II plasma and the reactor plasma except for the size. This is why ignition and burn in FIREX is so important.

In the FIREX-II project, the implosion laser is planned to be a 50kJ/3 ns blue laser, whereas the heating laser to be a 50 kJ/10 ps red laser. The physical size of the whole laser system will be relatively small to barely fit to the existing GEKKO building. Figure 4 shows the timetable of the whole FIREX project. The first experiment will start in FY2008, followed by the integrated experiment until the end of FY2010. The start of the FIREX-II project can be judged according to the success of the FIREX-I project. If the subsequent FIREX-II project will start as proposed, the ignition and burn will be demonstrated in parallel to National Ignition Facility and Laser Mega Joule so that both central and fast ignition schemes can be compared.

The Council for Science and Technology under the Ministry of Education, Culture and Sports, Science and Technology (MEXT) has positively evaluated the proposal of FIREX and made a recommendation to start FIREX-I in the report entitled “Future Direction of
National Fusion Research”\cite{9}. Subsequently, Atomic Energy Commission of Japan, Advisory Committee on Nuclear Fusion, has reported that “Based on its (FIREX-I) achievement, decide whether it should be advanced to the second-phase program aiming at the realization of ignition and burning” in the report entitled “National Policy of Future Nuclear Fusion Research and Development” \cite{10}.

Figure 5 shows a recent picture of the heating laser, that has a 4-beam and 4-pass regeneration amplifier system. For short pulse operation, broad band laser light has to be amplified. A high energy of 3 kJ/beam has been demonstrated at the broad band operation. The full beam equivalent of 12 kJ is above the design value.

**BEYOND FIREX**

The field of Inertial Fusion Energy (IFE) from the FIREX Project is on the verge of a transformational event with the expected achievement of central ignition within the next few years. It is imperative that the IFE community prepares for this event by agreeing on a credible plan for its development from scientific demonstration to commercial energy production.

At present, there are significant research programmes in the USA, Europe and Asia with plans for intermediate scale facilities for advanced ignition research such as FIREX-II, HiPER and various options within the USA including Advanced Radiographic Capability on NIF. These regional programmes need to be aligned into a single international strategic plan with coordination of the research at an international level. Coordination would accelerate the research and help to produce a program whose scale would be able to meet the critical need for clean energy production in a reasonable timescale. We envisage the coordination of our near term research in the period 2009-2012 to achieve a demonstration of energy gain of $Q = 0.1$ via advanced ignition schemes on FIREX-I and OMEGA-EP. Coupled with the achievement of central hot-spark ignition on NIF in the same period, the research focus would then move to the demonstration of high gain and the delivery of the enabling IFE technology. These programs would converge onto a truly international fusion demonstrator by 2030.

Inertial Fusion Energy development. If enough funding is given, power generation can be expected by 2030.

**SUMMARY AND CONCLUSIONS**

In summary, the proof-of-principle experiment has demonstrated efficient heating up to 0.8–1-keV temperature. Based on this achievement and previously achieved high-density compression, FIREX-I has started to demonstrate ignition temperature. Once the ignition temperature is achieved, FIREX-II should be started to demonstrate ignition and burn in parallel to NIF/LMJ ignition. Coupled with the achievement of central hot-spark ignition on NIF in the same period, the research focus would then move to the demonstration of high gain and the delivery of the enabling IFE technology. These programs would converge onto a truly international fusion demonstrator by 2030.

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**Fig. 1.** Concept of fast ignition. A hot-spark is created much faster than disassembly of the compressed core.

**Fig. 2.** Cone target implosions. The implosion density of cone targets does not very differ from that of non-cone implosions.
Fig. 3. DD neutron yields given as a function of the heating laser power.

Fig. 4. Timetable of the FIREX project. Given FIREX-II approved, ignition and burn may be demonstrated in parallel to NIF and LMJ programs.

Fig. 5. Heating laser LFEX (Laser for Fusion EXperiment), for FIREX-I.

Fig. 6. International-Laboratory Inertial Fusion Test (i-LIFT) would have a design goal of high average power IFE production, with net delivery of electricity and optimization of the fusion technology required for subsequent exploitation. A key goal would be to secure the engagement of industry and commercial investment for the ensuing deployment phase.

Fig. 7. A proposed plan for international demonstration of power generation by 2030.

REFERENCES

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