INTERVIEW: DR. YUANXI WAN

China's Ambitious Path to Fusion Power

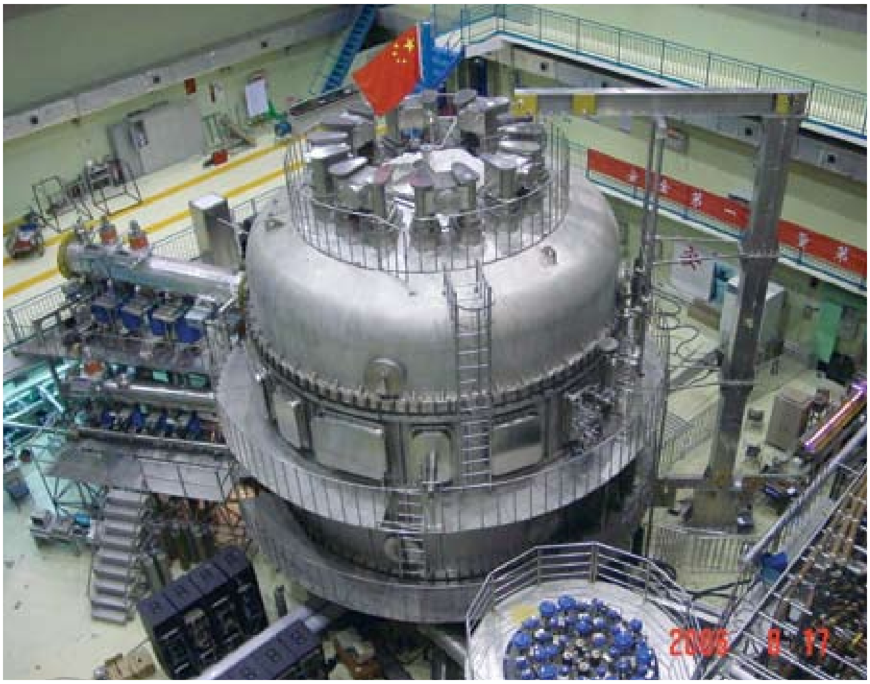
Question: Could you tell us a little bit about yourself?

Wan: My generation is a little different than the younger generation. We suffered when I was a university student. When the so-called Cultural Revolution happened, I was at Beijing University, the highest quality university in China. But fortunately, before I graduated from the university, the Cultural Revolution stopped, and we returned to a normal situation.

Question: What were you studying at the university?

Wan: Physics. When I graduated, I became a graduate student, also at Beijing University, but unfortunately, I was some kind of a "dangerous person," as part of the intelligentsia, because if you have independent ideas, you can see things and make judgments, by yourself. So, at that time, I "got a chance" to go to the big mountain area, near Tibet, in the underdeveloped area. And my wife, also from Beijing University, went to this mountain area. I became a worker, a farmer, and it lasted more than three years.

When the Cultural Revolution ended, the government realized that the intelligent person is very important, very useful. I had many classmates in Beijing, in the Chinese Academy of Sciences, and working in some institutes. Immediately, they, these classmates, introduced the fact that Dr. Wan is still in the big mountain area as a worker. When the Chinese



ITER

China's Experimental Advanced Superconducting Tokamak (EAST) was the first fully superconducting tokamak in the world. Mastering superconducting magnet technology is crucial for the success of the international ITER project.

Academy Sinica wanted to promote fusion research, immediately they sent an invitation to me, asking me to come to the Chinese Academy Sinica.

Question: What year was that, that you went to Beijing?

Wan: In 1973. I went to the capital city of Anhui Province, Hefei, not Beijing. At that time, in Beijing City, it was very difficult to get rights as a citizen, because the government controlled the level of population. The Chinese Academy Sinica wanted to promote fusion research, but they could not set up a new institute in Beijing. So the Beijing Institute of Physics

Dr. Yuanxi Wan is the Dean of the School of Nuclear Science and Technology at the University of Science and Technology in Hefei, Anhui Province, People's Republic of China. He is an Academician of the Chinese Academy of Sciences at its Institute of Plasma Physics in Hefei, where he has worked for more than 35 years. A pioneer in China's thermonuclear fusion program, Dr. Wan is described as the "mastermind" behind China's Experimental Advanced Superconducting Tokamak (EAST), the first fully superconducting tokamak in the world. On Jan. 9, 2009, on behalf of the EAST team, he received China's State Top Scientific and Technological Award from Premier Wen Jiabao.

Dr. Wan was appointed the chair of the ITER Science and Technology Advisory Committee in May 2010. He brings decades of experience, and an engaging sense of humor, to the international fusion development effort.

He was interviewed by Associate Editor Marsha Freeman on Dec. 1, 2010, during the annual meeting in Washington, D.C., of Fusion Power Associates. A version of the interview appeared in Executive Intelligence Review, *March 11, 2011.*

The Institute of Plasma Physics of the Chinese Academy of Sciences (IPPCAS) in Hefei, where Dr. Wan has worked for more than 35 years. China plans to train 2,000 skilled experimenters to carry out research and development in magnetic confinement fusion, according to a recent report in China Daily.

The TEXT tokamak at the Texas Fusion Research Center in Austin, where Dr. Wan worked for two years.

took the responsibility to found a new division in the city of Hefei. In 1973, I came back from the big mountain area, to the city of Hefei.

Question: And you are still there?

Wan: Yes, until now. For almost 40 years, I was fortunate to work on magnetic fusion research.

Opening the Door to China

Question: At that time, it must have started as a very small program.

Wan: In 1973, this was a new institute. I had the opportunity to join this special group, to set up a new institute. We learned a lot of things from Russia, from the United States, from other countries. At the beginning, I did not know what a tokamak was! I also didn't know what a plasma is. Because, when I was a graduate student, there was no plasma, just a theory. I majored in nuclear theory, and there was no special study of plasma for fusion.

The Chinese Academy Sinica's tradition is more open than the Academy of Sciences. It gives people more freedom, in this environment. Other organizations are sometimes more conservative, because they emphasize the political situation, and so on. But the Chinese Academy Sinica emphasizes doing scientific research. And worldwide, without international exchange and knowing other scientists, you cannot promote scientific research and accomplish a more rapid development.

My personal opinion is that former Chairman Deng Xiaoping, the chairman of our government, made the very important decision to open the door of China.

Question: How did this new policy affect the fusion program, and your research?

Wan: The whole of China changed. After I worked at the Institute of Plasma Physics in Hefei, I had the chance to visit other countries. First, I visited Germany. In 1983, I had the chance to visit the United States, in Austin, Texas, at the Fusion Research Center, to do experiments on the Texas Tokamak machine, TEXT. I worked in Austin for more than two years. This was an opportunity for me to learn a lot of things. At that time, there was a big difference between China and the United States, and between China and Europe.

Question: At that time, did China have any experimental fusion facilities?

Wan: Yes, a small tokamak, in Beijing. We had the CT-6—China Tokamak-6—at the Beijing Institute of Physics. A special group worked on this. The people in our Institute in Hefei learned a lot from this Institute. We grew very quickly, and that special group in our Institute became much larger than the group in Beijing. Also, we designed and built a small tokamak, that we called HT-6; and then, the HT-6B, and HT-6F, two small tokamaks. We did it ourselves: designing, fabricating, and assembling this tokamak.

So, from the time that China opened the door, our Institute had the chance to communicate and exchange information with other institutes abroad.

Compared to the young generation, I am unlucky. Compared with the old generation, I'm lucky.

Question: Why is that?

Wan: Because the young generation right now, doesn't need to go to the countryside; they never suffered the Cultural Revolution. I am lucky, compared to the older generation, when some people could *not* do scientific research during the Cultural Revolution. And after the Cultural Revolution, time passed, and they were older, and some died. So many people.

Question: How did fusion research in China progress?

Wan: Our Institute grew very quickly; also, fusion research, overall, in China. From the small project, developed a medium-sized program. Then, China was able to join the ITER, International Thermonuclear Experimental Reactor project in 2003.

Question: Your frontier fusion project now is the Experimental Advanced Superconducting Tokamak, or EAST. It is my understanding that this was the world's first fully superconducting tokamak. In 2009, I visited the KSTAR superconducting tokamak in South Korea, which is newer, but yours was first.

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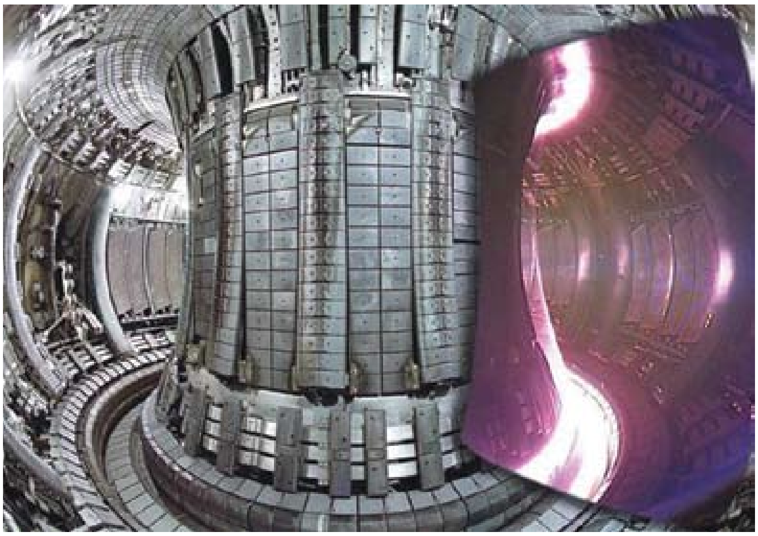


EFDA, JET

Inside the General Atomics Doublet III (above) and the Joint European Torus (JET). Both reactors made significant progress toward a burning plasma condition. The JET is shown both before and during (at right) operation.

Wan: Thank you. You remember! We collaborate, exchange, support, and compete with each other.

Toward a Superconducting Tokamak

Question: What was your reason for building EAST? What were your goals?

Wan: Our Institute developed very openly. We learned a lot from the United States, and also from Russia. We realized that for the tokamak, this device, the final goal must be fusion energy. At that time, fusion research on tokamaks had already made significant progress. For example, on the DIII-D, JET (Joint European Torus), TFTR (Tokamak Fusion Test Reactor). But still the tokamak, even with this significant progress, still is not a real fusion energy device, because although the tokamak has gotten to the burning plasma condition for fusion power, it is temporary, for only very short time.

For example, on the JET, even though it made significant progress, we say this is a scientific demonstration. Just three shots using hydrogen and deuterium fuel were used to produce the fusion reaction, to get a maximum of fusion power, of about 16 megawatts. But only with a few shots, and each shot lasts only a few seconds. This is not real fusion energy. But it is significant progress, because it got to the real fusion reaction, but it was only temporary.

If you want to go to real fusion energy, you must prolong this discharge even more, and go to a steady state. If the tokamak can go to the burning state in a steady-state condition, then you can produce a lot of fusion energy. Our Institute said we must make a contribution to this final purpose. What kind of technical path can we take to a superconducting tokamak?

At that time, we had already imported, shipped, the first superconducting tokamak, the T-7, from the Kurchatov Institute in Russia to our Institute.

Question: You brought the Russian tokamak to China?

Wan: Yes, because the T-7 was the first superconducting tokamak in the world. But it is not fully superconducting—just a part of the magnet was made of superconducting material. It was the toroidal magnet that was superconducting, but the others are normal. It was the first tokamak to demonstrate that superconducting technology can be used on the tokamak magnetic-confinement device. This was very useful. But this machine in Russia was used just for engineering testing, just to gain experience on how to use superconducting magnets on the tokamak.

Question: They were not concerned with producing fusion energy? It was just for testing?

Wan: It is a small machine. Even for physics experiments, its capability is poor. When the Russian situation changed quickly, when the Soviet Union collapsed, everything was stopped, including some fusion research. This machine was in the garbage. So we discussed this with the Kurchatov Institute, and we shipped this machine to our Institute, because in China, there was not enough of a budget to support fusion research.

China did not have enough money to support fusion research, but we were able to use the used equipment from France and Russia, and we shipped this used equipment to our Institute and worked on it. It was maintained, reassembled, and so on. It was made up of a huge number of components, and was very dirty! It was totally unusable. This was a way of training for us. Even though the quality of the equipment was very poor, in our workshop, the scientists and technicians worked together, and we cleaned every component. We reassembled all of the equipment. We learned a lot about the tokamak.

It was a difficult time, because it was very difficult for our Institute to get budget support for fusion research. So we used our good relationship with foreign countries, and fusion laboratories, to get used equipment.

Question: When was this?

Wan: We shipped the Russian tokamak in 1992, and, in 1994, reassembled it ourselves in our workshop, and we started experiments. So the first fully superconducting tokamak today is the HT-7, which had originally been the T-7 in the Kurchatov Institute.

Question: Why did you rename it the Hefei tokamak?

Wan: We modified the vacuum chamber, and modified other components, and just kept the superconducting toroidal field magnet. We did a lot of experiments on this machine. At the same time, significant progress had been achieved on other machines, and we realized that a superconducting tokamak should make more of a contribution for a fusion reactor. Because to go to a real steady-state operation of a tokamak, you must get to full superconducting operation, which means including the poloidal magnet. So we decided to design a full superconducting tokamak.

Question: When did the government approve the EAST project?

Wan: In 1997. Once they made the decision, we decided to design an advanced configuration in the full superconducting tokamak. This means that the plasma cross-section is elongated, in a "D" shape. The TFTR and JT-60 have a plasma cross-section which is a circle, but the JET is elongated, and is more advanced. This design is very similar to ITER. We made these decisions: one, for the superconducting tokamak, and second, with an advanced configuration.

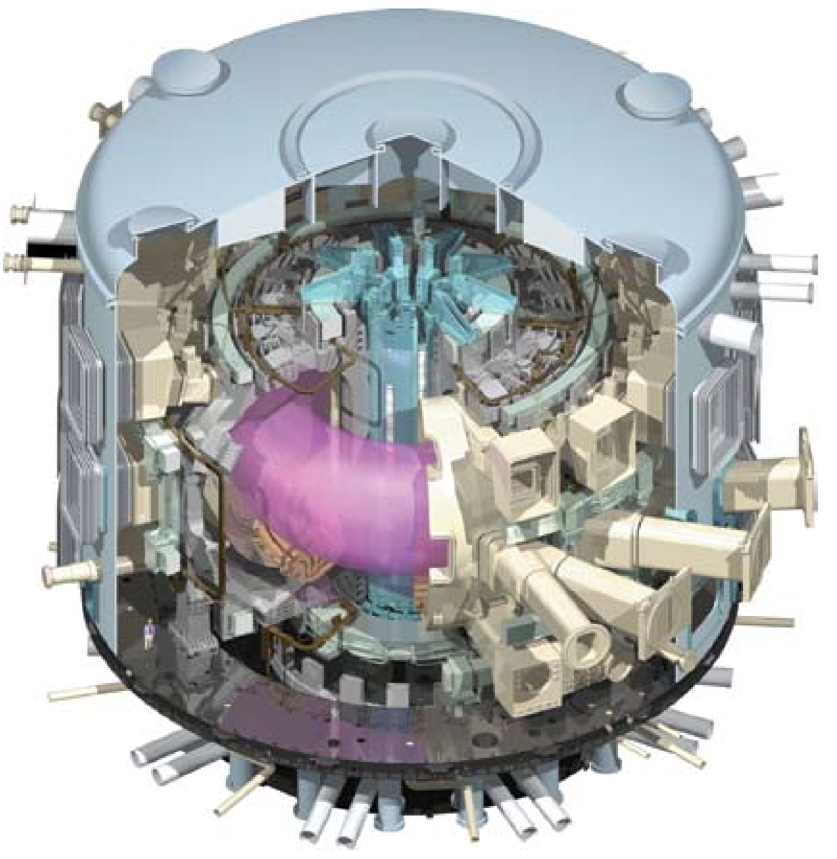
Freedom to Collaborate

Question: So your design did not depend upon the final design of ITER. You felt that, in any case, this was the pathway to follow?

Wan: Yes. But we learned a lot of things from the Princeton Plasma Physics Lab TPX (Tokamak Physics Experiment) work. George Neilson was the manager of that superconducting tokamak.

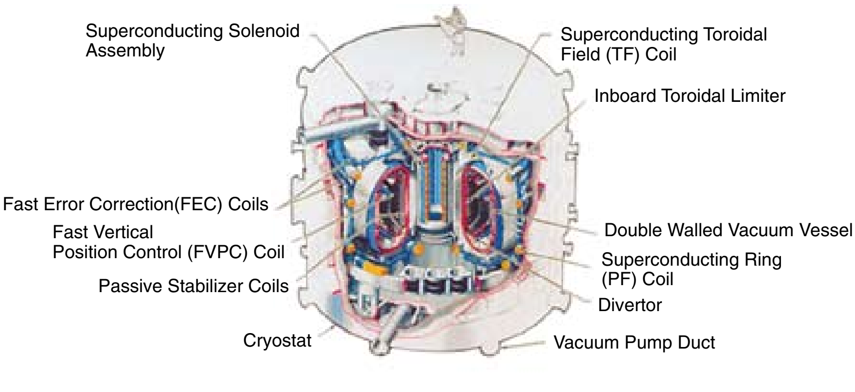
IPPCAS

The HT-7 tokamak at IPPCAS, which was shipped from the Kurchatov Institute in Russia in 1992, and reassembled and modified at IPPCAS.



ITER

Cutaway illustration of the 8-story-tall, 30-meter-diameter ITER, with a burning plasma depicted. Now in construction, ITER will be built over the next decade with contributions from Russia, the United States, Europe, Japan, South Korea, India, and China.



PPPL

The TPX (Tokamak Physics Experiment) at Princeton Plasma Physics Laboratory was designed as a follow-on reactor to the successful TFTR (Tokamak Fusion Test Reactor). But the TPX, a long-pulse machine, was killed in the engineering stage.

Unfortunately, the United States spent some money for a few years, and then stopped. Also, people from the Kurchatov Institute, about 100, came to work at our Institute, engineers and scientists. We all worked at our lab, together. It was totally international. Fortunately, because magnetic fusion is a totally peaceful project, there is a lot of freedom for the exchange of ideas and ability to communicate with each other. It is very open, which promotes the research, which can then move forward quickly.

When we proposed our EAST project to the central government, there was competition with other projects. So we improved our design, and argued many points to improve our design. Finally, the experts committee voted, and supported our project as a national project. We got special budget support, for construction of the EAST machine. I also visited PPPL (Princeton Plasma Physics Laboratory), General Atomics, and the Tore Supra, which is another superconducting tokamak of the French. The government realized that the superconducting tokamak, worldwide, had very strong support, and has a good foundation for development.

Even though I say there was full support for our EAST project, in fact, our budget is only about U.S.$30 million, in total. But, more than 15 years ago, this was a quite large budget compared to others.

Question: South Korea, your neighbor, is also pursuing fusion research developing superconducting magnet technology. Do you compete?

Wan: South Korea's fusion budget is more than 20 times higher than ours. The funding was short for us, so I made the decision that everything would be designed and fabricated by ourselves. All of the superconducting conductor was made by ourselves, in our workshop; all of the magnets, we made ourselves. And even the cryogenic systems, which you can buy on the world market, we fabricated ourselves. We assembled this tokamak by ourselves.

We had to seriously control the quality, during the manufacturing process, for the superconducting magnets. This will also be the case for ITER. When you finish manufacturing one piece of the superconducting magnet for ITER, you will cool it down to test it. But when you assemble all of the sections of the magnet together, you cannot test it at the low temperature. So, at room temperature, you are assembling all of the magnet together. You manufacture some joints, and so on, at room temperature. There is no way to cool down these parts to test whether the quality is good or not, beforehand. So, you must seriously control the quality another way.

Question: I understand that one of the proposals that has been put forward to cut down the cost of ITER is to test parts of the coils, but not the whole magnet, and to cool it down to liquid nitrogen temperature, not liquid hydrogen, which

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France's Tore Supra superconducting tokamak.

www.defenceforumofIndia

India's Steady State Superconducting Tokamak, SST-1, in development at the Institute for Plasma Research. IPR is involved in research in various aspects of plasma science including basic plasma physics, research on magnetically confined hot plasmas, and plasma technologies for industrial applications.

EAST researchers celebrate the first plasma discharge in September 2006.

ITER

The sixth ITER council meeting, which took place in Suzhou, China, in 2010. Below, the ribbon cutting ceremony at the meeting.

ITER

EAST is a national project, supported by the central government. Here, He Guoqiang, secretary of the Central Commission for Discipline Inspection, visits EAST along with other government officials.

is what it will require. Is that very risky?

Wan: With the superconducting tokamak, you always take a high risk, because there is no way you can test the whole magnet. For our EAST machine, as you said, this was a risk. So I made the decision that each piece of the magnet would be cooled down and tested separately. The whole magnet is too large. As each segment is cooling down, you check for leakage. You can only cool it down, piece by piece. You join them together at room temperature in the final assembly stage.

Question: So, the first time that the whole magnet will be cooled down to become superconducting, is when it is in the tokamak?

Wan: Yes. You have to pump down the cryostat which covers the vacuum vessel and magnets. If you had to take it apart to fix the leak, it is a more complicated process than the initial assembly.

India is facing this kind of problem. They made the announcement that they had finished the final assembly of their device, and would test it. But when they cooled down the magnets, they had a leak. There is no way you find the leak or fix it. You can only disassemble it totally. This is the risk.

Question: That's why Dr. G.S. Lee was nervous when we were visiting the KSTAR superconducting tokamak in South Korea, because they were cooling down the magnets for the first time, and he was calling the laboratory in the middle of the night, worried about a leak.

Wan: Me too! for the week of the cooling down. With some materials, if you cool down to liquid nitrogen (77°K), there is no leak. But sometimes, when you cool down to liquid helium (4°K), there is a leak. When it turns warm again, the leak goes away, and you cannot find it.

For example, in Germany, the W7X, the Wendelstein stellarator, suffered this kind of leakage, and they still don't know where it is. You cannot go to low superconducting temperature because you do not have a good enough vacuum, because of the leak. For ITER, we emphasize, especially for the magnet, during the fabrication process, quality control is more important than anything else. The final assembly will take several years, so it is very important. ITER is so large. I think Dr. Lee is right. He said during the fabrication process of the magnet, quality control is the most important.

For our EAST, I cooled down and tested all of the magnets. I did not find any problem, fortunately. So up to now, we have done 14,000 discharges, a few hundred per day, of electromagnetic pulses on the components. The tokamak itself has not had any problems, just the facing components, facing the very high-temperature plasma. But this is no big problem, because you can look through the win-

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Technicians at the Institute of Plasma Physics in Hefei with a model of ITER's superconducting correction coils.

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Scientists at the Institute of Plasma Physics in Hefei work on the jacketing of superconducting cable for ITER.

dow into the vacuum chamber, and maintain and change these components.

The Materials Question

Question: Do you have to do this maintenance using remote handling?

Wan: Remote handling is only needed for a burning plasma when you use deuterium (D) and slightly radioactive tritium (T). For EAST we just use helium and deuterium, so there is no radioactivity and no problem. This is an experimental device. Inside the vacuum chamber, all of the components can be changed through the window directly after you do experiments. For ITER, we are still arguing about this. The design of some ITER components, still right now, is not totally solved.

For example, what kind of material will be used for the first wall? This is still under development. Should we use CFC (carbon fiber composite) material, tungsten, or some other material? This is under investigation. First we must use a CFC. But before the D-T (deuterium-tritium) charge, we have to change to tungsten. I hope this is not too specialized. Many plasma physicists don't understand this!

Question: Materials have been a challenge for operating in a fusion plasma environment.

Wan: I agree with you. Outside the fusion community, some people will say: "You have not resolved the materials problem for a tokamak, to be able to go to a reactor." And it is true. But I divide the materials question into two different problems.

One, is the first-wall material. It directly faces the high-temperature plasma. So, when the plasma's energetic particles are pumped and go to the first wall, which has a high heat flux, heat load, it can damage some components. Even though the plasma is magnetically confined, the high-temperature ions still create a high heat flux for the first-wall material. We have to choose the material which can suffer a high-density heat load, so, even if it erodes, and the first wall material can enter the core of the plasma, it cannot be allowed to influence the core plasma. This would cause an impurity, which will decrease the temperature, and cause a disruption. You cannot sustain fusion reactions with a dirty plasma (i.e., with impurities).

Another material problem is, that, even if the first-wall material can suffer the high temperature, the fast neutrons will penetrate the first-wall blanket. The material for the blanket is inside some very complicated structural material. The neutrons are at a very high flux. We do not have any evidence that any material can survive this. We have developed materials to survive the first wall heat flux. They are not good enough, but we can use it temporarily. But for the high neutron flux, up to now, there is no experimental data on what kind of material can be used, because we don't have a neutron source for testing new materials.

That is why, when the international fusion community made the decision to construct the ITER project, some scientists

ITER

Members of ITER's Magnet Division spent a week at the Institute of Plasma Physics in Hefei, where work is ongoing on the design of the magnet feeders. Here team members look at the first bending and insulation trials on conductor dummy lengths, which will be used in the electrical connections to the magnets around the tokamak. These provide flexibility for thermal contraction as the magnets are cooled to liquid helium temperatures.

made the proposal to construct another test facility, IFMIF, the International Fusion Materials Irradiation Facility. It is an accelerator. It would be a very huge and expensive facility. It would use an accelerator to produce neutrons to get the experimental data, and see what kind of material can suffer a neutron environment. This is the second-most serious problem.

But fortunately, all of this blanket and first-wall material is changeable. You can change the blanket and maintain it through the windows. The lifetime may be 20 years, I suppose, if you can develop a new material. If you cannot, then, in three or five years, you can change it. It is a serious problem, but it is not impossible. The question is just the lifetime of the components. We should develop materials, and do many kinds of tests to get a high quality of material. Then we can increase the lifetime of these components, which means decreasing the price of fusion energy. Otherwise it will be very expensive, in competition with other energy resources.

ITER

Ultrasonic inspection for cracks of 30 prototype low carbon central solenoid jacket sections for ITER, produced by Baosteel in Shanghai, under an ITER contract. The sections will undergo compaction at the jacketing line in Kyushu, Japan, and then be sent to Oak Ridge National Laboratory for preliminary winding trials.

Nuclear Power in China

Question: While developing fusion technology, China is carrying out a very ambitious nuclear energy development program, unlike the United States or western Europe.

Wan: China right now is only 1 or 2 percent nuclear. You can use solar, and wind, hydropower, but that is only part of global energy. So nuclear power is the solution, because if you really think CO_2 causes the "greenhouse effect," and you must control this, nuclear power stations are good.

Of course, safety has been a problem. In Russia they had a big accident. In the United States. after an accident, it stopped. But now, the safety has improved a lot. An airplane looks terrible in terms of safety, but the airplane is safer than riding a bicycle in China. So, finally, people are realizing that nuclear power stations are safer and cleaner.

So I think more and more countries are changing their ideas.

Question: Although you are starting from a relatively small nuclear energy base, the projected rate of growth is impressive. And you are looking toward the next 20 or 30 years. Can you talk about the fission-fusion hybrid project that you have proposed be developed, as the bridge between fission and fusion?

Wan: China must develop fission power stations as rapidly as possible. Otherwise we have a big pollution situation, not just domestically, but internationally. Right now, about 70 percent of our energy comes from coal. It is terrible. It is the highest percentage in the world. If you consider that the population is so large, the absolute amount of coal China uses each year is very huge. So China must decrease this, and fission power is a good way to decrease the primary energy resources from coal. The government and the public support the rapid development of nuclear power stations.

In a nuclear power station, you can only use about 1 percent of the uranium, so, very quickly, there will be a shortage of uranium—in less than 100 years. So this is one problem. The second problem is the waste, which is increasing very quickly, year by year. This is also very dangerous.

So, how do you deal with these kinds of problems—the shortage of material and the waste? Of course, you can develop a fast breeder, which needs time. Also, the efficiency is quite low.

If the tokamak fusion reactor is successful, you can use the fusion neutrons to irradiate uranium-238 into plutonium-239 for fission fuel. Also, you can use the neutron source to transmute the waste, which is safer. To do this, you don't need a pure fusion power reactor, which still has the materials problem. If you use the hybrid concept, you can use a little pure fusion in a cold plasma, which means that the neutron flux is much lower than in the pure fusion power station. But you can use the fusion reaction in the blanket to amplify the output of energy. You can breed fission material, and treat the fission waste.

This is a benefit for both sides: for fusion, you can promote the development of fusion technology, of materials development, so you can get an early application for fusion, and, at the same time, benefit fission. This is the best idea.

Twenty years ago, many Europeans and Americans didn't support this idea, because, coming from the political point of view, they thought you will produce a lot of plutonium for nuclear bombs. I say that the energy problem is more dangerous than the nuclear bomb. The next generation, and several after, will face a serious problem [without nuclear energy].

In South Korea, India, Russia—I heard, even in the U.S.—more and more people support this fission-fusion hybrid concept.

Question: The hybrid concept was put forward in the United States 30 years ago. Dr. Edward Teller strongly promoted it, as a bridge between fission and fusion. But it was never developed here.

Wan: The first director general of ITER, the Frenchman Paul Henri Rebut, talked with me about it one day, in China: that the hybrid is the best way to use nuclear energy, combining fission and fusion. Right now, it looks like everyone agrees on the concept of a hybrid. So China would like to do this. But first, the tokamak reactor has to be a success.

So right now, in the meantime, we will use an accelerator to produce the neutrons, not a fusion reactor, for breeding nuclear fuel and to transmute the waste, and so on.

Question: But you're not going to wait to see if the ITER tokamak reactor is a success before going ahead with your own program?

Wan: I think that the tokamak program has already made significant progress, on JET, TFTR, on JT-60. The tokamak can really go to a burning plasma. Some scientists in China say, ITER is not clearly a success. Why do you want to construct another machine?

The tokamak has a very strong basis, which comes from all of the experiments that have been done. We summarized all of the experiments that were done, to get the scaling law from the previous experiments, and then extrapolated. So we have very strong confidence that ITER will be a success. I think there is no problem for ITER to go to the 400 megawatts of burning plasma.

I use this argument with others: China should prepare before ITER is fully successful. We should design and do some R&D, and maybe construct our hybrid test reactor. We have already made this kind of proposal to the government. But many projects compete, and they criticize each other! So we will continue to do this. Our Institute is in competition with others, who continue to criticize.

Question: When you look at China's nuclear program, you see that the government does understand that the country needs an adequate supply of energy, and takes responsibility for infrastructure. That has not been true here in the United States.

Wan: Twenty years ago, being in the United States was a big surprise for me, but now, for Chinese people who go to the United States, it is no big surprise, because the highways in China are also developing, especially around the big cities.

Question: And the United States has been going dramatically in the wrong direction. I am sure you are aware, for example, of the housing crisis; we have people who have lost their homes, and are living in their cars.

Wan: People in China are following the situation in the United States.

Question: People are living in their cars?

Wan: Yes. In Beijing, rush hour is terrible, more terrible than in New York!

China should learn some things from other countries, but also not to make some mistakes.

Looking to the Future

Question: The political leadership of China has said it is not going to do what was done in Russia after the fall of the Soviet Union, with the privatization of that nation's economy and national patrimony. It is a disaster.

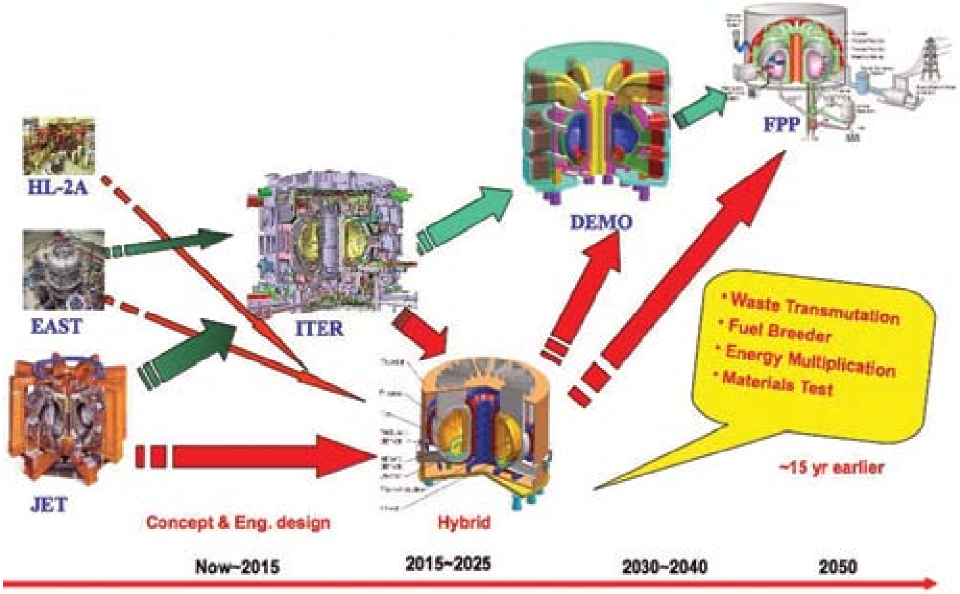
Wan: I was in Moscow in 1992, to get the T-7 tokamak shipped. Moscow was terrible. There was a food shortage, and there were no products for sale.

To come back to the hybrid: after I made the presentation, several people invited me to join in a workshop in the United States, and one in Italy. More and more people realize this could be a good choice.

I don't know if the Chinese government will make an early decision to build the hybrid, or not. The big problem for

POSSIBLE FUSION ROAD MAP TO DEMO IN CHINA

The next step proposed for China's fusion program is a fusion-fission hybrid, to be built while ITER is under construction. The fusion neutrons would be used to breed fuel for, and burn waste from, China's fission reactors, while tackling the technological challenges of fusion.



our magnetic fusion community is this: Most experts in China say "Your magnetic fusion community has already gotten a huge budget to support ITER. You are so rich! So please wait for 10 years, until you are fully successful with ITER, or with EAST. Then, maybe, the government will give you more support."

But I think time is very important. We should overlap the projects. This is long-term research, to solve the big problem of energy in China. So we must make the decision in advance. People always ask, "What is your schedule?" I say, my personal opinion is, that to make the decision is most important. Otherwise, there is delay, delay, delay. In fact, the schedule is not determined by the design, construction, assembly, and so on. It is determined by the decision.

For example, for ITER, the beginning was more than 20 years ago. They finally made a decision to build it, but after 20 years! Twenty years, just to make the decision! But the construction will be only 10 years. This is not reasonable.

For our EAST machine, we took only about five years to finish the design and fabrication of the components and assembly, and finally, we got the first plasma, in 2006; about a year and a half before KSTAR. I think making the decision as soon as possible is very important.

Question: You also need to keep momentum, if you want to bring in young people. How long will you be doing experiments on EAST? Will they continue until ITER is operational?

Wan: I think we can continue experiments on EAST for 10 years. Before ITER is in operation, both EAST and KSTAR can make different kinds of contributions to ITER, so we should use them both as much as possible to get technology development and support. ITER is an experimental reactor, so it is necessary to make broad investigations in many technologies—how to control the plasma to go to steady-state operation, how to profile the plasma, and so on. It is a very sensitive and very complicated technology. How to heat it and keep the plasma current is also a very complicated situation. If you do the research in depth, in the future, the tokamak reactor can be simpler.

So we will continue to do these kinds of experiments.