An interview with Dr. Jie Zhang

Dr. Guoqing Chang

Dr. Jie Zhang was giving a talk at the conference HPLSE 2018

Dr. Jie Zhang, a distinguished physicist, has made significant contributions in the fields of high-energy density physics and inertial confinement fusion. Because of these, he was elected academician of the Chinese Academy of Sciences in 2003, academician of the German National Academy of Sciences in 2007, Fellow of the Academy of Sciences for the Developing World (TWAS) in 2008, foreign member of the Royal Academy of Engineering in the United Kingdom in 2011, and foreign associate of the National Academy of Sciences in the United States in 2012. In 2015, he was awarded the prestigious Edward Teller Medal, the most important international award in inertial confinement fusion and high-energy density physics. In 2021, he was awarded the Future Science Prize in Physical Sciences.

Dr. Jie Zhang is also an eminent educator in academia. In 2009, he founded the Zhiyuan College at Shanghai Jiao Tong University and served as its dean until 2014. He proposed and implemented the Zhiyuan Model. Because of the successful practice at the Zhiyuan College, he received the First Prize of National Teaching Achievement Award in 2014. Returned to the classroom in 2018, he continued teaching to cultivate innovative talent combining his lifetime of experience and wisdom. He won the Fourth National Distinguished Teaching Award in 2023.

He is also a master in management. From 2003 to 2006, he served as the head of the Chinese delegation for Sino-U.S. high-energy physics cooperation, resolving many systematic and institutional issues during Sino-US cooperation and exchanges. His efforts received high recognition from both China and the United States and were described by Professor Tsung-Dao Lee, one of the first Chinese Noble Laureates, as his "closest friend beyond age". From 2006 to 2017, he served as the President of Shanghai Jiao Tong University, proposing and implementing a modern university governance system based on institutional incentives. He promoted comprehensive reforms in innovative talent cultivation, scientific and technological innovation, cultural heritage innovation, and social service innovation, successfully elevating Shanghai Jiao Tong University to the ranks of world-class universities.

Dr. Chang Guoqing: How did you enter the field of high-energy density physics?

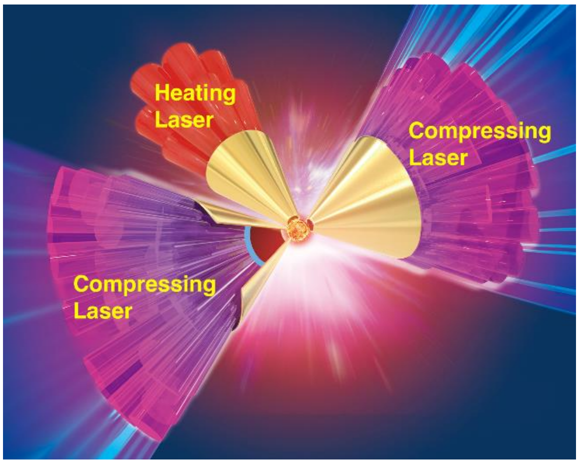
Dr. Zhang Jie: I first studied ultraviolet wavelength lasers, then moved on to X-ray lasers, and eventually delved into laser- nuclear fusion and high-energy density physics. It was a continuous evolution. My curiosity about the states and motion of matter under high temperature and pressure (extreme states of matter) initially led me to investigate high-energy density physics. Later, the drive to study laser- nuclear fusion reactions stemmed mainly from the pursuit of humanity's ultimate energy source. During my doctoral research from 1985 to1988 at the Institute of Physics, Chinese Academy of Sciences, and subsequent work undertaken at the University of Oxford and Rutherford Laboratory in the UK during 1989-1998, my initial goal was to invent laser emission towards shorter wavelengths even to x-rays. To generate stimulated radiation within the X-ray band, population inversion must be induced at highly ionized ionic energy levels, which is achievable only within a plasma state at extraordinarily high energy densities. After many years of collective efforts, our research team successfully extended the saturated output wavelength of X-ray lasers to reach the vicinity of the "water window" (2.2–4.3 nm). From 1995 onwards, we started investigating fast ignition laser fusion processes and physical processes under ultra-high spatiotemporal resolution.

Dr. Chang Guoqing: Why is high-energy density physics important?

Dr. Zhang Jie: The universe originated from an extremely high-energy density event, the Big Bang, which occurred approximately 13.8 billion years ago. The ongoing evolution of the cosmos is closely related to high-energy density physical processes. In the observable universe, over 95% of matter exists in forms of high-energy density, whereas the solid, liquid, and gaseous states commonly found on our Earth are in fact extremely rare in the cosmos. Studying laser fusion processes on Earth requires compressing deuterium-tritium fuels to extremely high temperatures and densities in a very short time, triggering a nuclear fusion reaction of the deuterium-tritium nucleus. The energy density required for nuclear fusion reactions exceeds 350 billion atmospheric pressures, representing an extremely high-energy density state. The energy density further increases after the fusion reaction, allowing us to study even more extreme unknown states in the universe. This field is a pivotal frontier in scientific research as it promises to unlock the secrets of the higher-energy-density phenomena that underpin the fabric of the cosmos.

Dr. Chang Guoqing: You proposed the double-cone ignition (DCI) scheme of laser-fusion. What are the advantages of this approach?

Dr. Zhang Jie: First of all, Deuterium-tritium nuclear fusion fuel is virtually inexhaustible, and the reaction products have no long-term radioactivity. Besides, the energy density of nuclear fuels per unit mass is over ten million times higher than fossil fuels. Therefore, to ultimately address the sustainability challenges posed by carbon-based energy sources, we will inevitably choose safer, more efficient, and cleaner nuclear fusion energy. In order to meet the ultimate energy needs of sustainable development as well as to ensure national strategic security, it is essential to achieve controlled nuclear fusion reactions. However, achieving controlled nuclear fusion reactions is an immensely challenging task that has been pursued for 50 years.



DCI

In 1997, while working at Rutherford Laboratory in the UK to address the physical challenges of fast ignition in laser fusion, I proposed the original idea of creating an isochoric plasma by head-on collision of high-density plasma jets from gold cones. This was named as cell-in-cone. In 2018, after I finished my administrative duties as an associate president of the Chinese Academy of Sciences, I proposed the double cone ignition (DCI) scheme, based on the cell-in-cone idea and incorporated recent advances in laser fusion processes. The DCI scheme is designed to completely separate the compression process and the heating process of laser fusion, so as to reduce the hydrodynamic instability in the final stage and improve the heating efficiency. This scheme includes four closely related and successive processes: (1) isentropic compression inside the cones, (2) centripetal implosion acceleration, (3) density doubling and collisional preheating (4) fast electron heating under magnetic field guidance. Compared to the indirectly driven central ignition scheme, DCI has advantages such as higher heating efficiency and lower hydrodynamic instability, significantly improving the energy efficiency and controllability of laser fusion reactions.

Dr. Chang Guoqing: What is the current experimental progress of DCI?

Dr. Zhang Jie: Since the proposal of the DCI scheme, we have conducted a series of rigorous experiments using Shenguang II Upgrade laser facility and other smaller scale laser facilities to refine this innovative approach. Meanwhile, several international teams are also exploring in this field. Starting in 2018, I assembled a large joint research team, consisting of more than 300 researchers and students from six Chinese Academy of Sciences institutes and ten universities. Until the end of 2022, we conducted 8 rounds of big experimental campaigns, and successfully validated the four key physics processes and demonstrated the high-efficiency robustness of the scheme. Through the whole year 2023, the Shenguang II Upgrade laser facility was under energy-doubling from 8 beams to 16 beams for 10 more experimental campaigns by 2026. Our ultimate goal is to demonstrate high-gain ignition at further upgraded Shenguang X laser facility.

Dr. Chang Guoqing: How did you balance research and management during your tenure as President of Shanghai Jiao Tong University from 2006 to 2017?

Dr. Zhang Jie: The mission of a university is to cultivate talent, and being a university president requires a significant amount of time dedicated to studies on higher education. Additionally, there are numerous administrative tasks both internally and externally. Regular interactions with teachers and participation in various extracurricular activities with students are also essential. Out of respects for the role of a university president, during my tenure at Shanghai Jiao Tong University, I minimized the time devoted to my own high-energy density physics research. I typically supervised only one doctoral student at a time, fully participating in their scientific discussion to maintain sensitivity to innovation and stay abreast of the latest research frontiers. Meanwhile, I spent a lot of time on how to rapidly improve the quality of university through the establishment of an efficient governance system in China's rapid transformation, and published relevant academic papers on higher education. Over the decade, together with my colleagues, we proposed and implemented a modern university governance system centered on institutional incentives, promoting comprehensive reforms in innovative talent cultivation, scientific and technological innovation, cultural inheritance and innovation, and social service innovation. These successfully upgraded the positioning of Shanghai Jiao Tong University among the world-class universities.

Dr. Chang Guoqing: Since 2021, you have served as the second director of Tsung-Dao Lee Institute in Zhangjiang Science City, Shanghai. Can you introduce the current work of as the director of Tsung-Dao Lee Institute?

Zhang Jie: Tsung-Dao Lee Institute was officially established in 2016, with the scientific mission of leveraging the advantages of large-scale scientific research paradigms and high internationalization. It aims to achieve fundamental breakthroughs in the origin, evolution, and structural formation of matter under extreme conditions in three directions: passive, active, and evolutionary. The goal is to become a world-class basic research institution. Inside the building of Tsung-Dao Lee Institute, there are two experimental platforms and a large supercomputing platform. These three research platforms provide the most extreme exploration capabilities for investigating matter under extreme conditions and offer high-spec computing resources for research such as lattice quantum chromodynamics.

In addition, we are utilizing the unique natural conditions in different geographical locations in China to construct three advanced observation bases with extreme detection capabilities. The first is to upgrade the PandaX liquid xenon detector, located in the Jinping Mountain deep underground laboratory in Sichuan at a depth of 2400 meters. It is primarily for direct detection of dark matter particles. In the next five years, the detector will be upgraded from its current 4-ton mass to 30 tons to promote the detection power by about two orders of magnitude. The second is the JUST Spectral Survey Telescope located at an altitude of 4500 meters on the Shaishiteng Mountain in Qinghai, designed for probing dark universe phenomena. The third is the TRIDENT neutrino telescope, being built at a depth of 3500 meters in the South China Sea of Hainan, to detect the extreme high-energy neutrino sources from the early universe.

Combining theory, experiments, and observations, by fully taking advantages of large-scale scientific research paradigms, we hope to provide the best research capabilities for scientists at Tsung-Dao Lee Institute. Our aim is to delve into the most fundamental and basic scientific questions about the universe, explore the limits of nature, and expand the boundaries of human knowledge.

Dr. Chang Guoqing: Can you comment on Prof. Lee's contribution to the development of science and technology in China?

Dr. Zhang Jie: Prof. Lee has been an influential proponent of the advancement of science, technology, and higher education in China. His strategic contributions have been pivotal, ranging from the early inception of establishment of the School of the Gifted Young (SGY) at the University of Science and Technology of China to advocating for the full reinstatement of the National College Entrance Examination. These initiatives have substantially accelerated the resurgence of China's scientific and educational vigor. Dr. Lee was the architect of the China–United States Physics Examination and Application (CUSPEA), a talent-nurturing program that has significantly bolstered bilateral academic exchange and development. He played a key role in recommending the establishment of the National Natural Science Foundation of China (NSFC) as well as the postdoctoral system in China, even contributing to the design of the inaugural emblems for both the NSFC and the Chinese Postdoctoral Science Foundation.

Moreover, at the beginning of the reform and opening-up, Dr. Lee grasped the opportunity of Mr. Deng Xiaoping's first visit to the United States in 1979 to push for the formal signing of the high-energy physics cooperation agreement between the governments of China and the United States. This established the mechanism for Sino-U.S. scientific and technological cooperation, playing a crucial role in China's reform and the flourishing of its high-tech sector. It also served as a bridge for exchanges and cooperation between China and the United States. Personally, I had the honor of serving as the head of the Chinese delegation for the Sino-U.S. High Energy Physics Cooperation Mechanism from 2003 to 2006, working directly under the guidance of Dr.

Li, receiving his high recognition, and being honored by him as his "close friend beyond age."

Dr. Chang Guoqing: Have you encountered difficult moments in your scientific research, and how did you overcome them?

Dr. Zhang Jie: As a physicist, I face new challenges every day, and failures far outnumber successes. However, I am an optimist who enjoys accepting challenging tasks. Overcoming difficulties relies on persistence and never giving up. Scientific research is inherently not smooth sailing, and an optimistic mindset and a spirit of never giving up are indispensable. For example, developing an electron diffraction apparatus with atomic-scale ultrafast time resolution requires substantial financial support. Since 2011, we started applying for major innovative projects of the Instrumentation and Equipment Program of the NSFC. Despite the team's full efforts, we failed twice in two consecutive years at the last round of the defence. We did not give up until June 2013 when we finally secured the project. After more than five years of hard work, in 2018, we successfully developed one of the world's few ultrafast electron diffraction and imaging experimental apparatuses with a mega-electron-volt energy level and sub-angstrom resolution for structural changes. We also improved the time resolution of ultrafast electron diffraction to better than 50 femtoseconds, breaking the world record. Later, in collaboration with partners, we successfully used light fields to control the dimensions of quantum materials and observed instantaneous light-induced novel material states. We applied these new technologies to observe transient processes in important physics and chemistry fields, such as miniaturized high-energy particle accelerators, phase transitions, and single-molecule imaging.

Dr.Chang Guoqing: What are your hobbies in spare time?

Dr.Zhang Jie: I enjoy reading, particularly history and economics books. Sometimes, I also read literature and military-themed books. The paper books I read are usually related to my profession. For non-professional books, I mainly listen to them, especially during activities like driving, exercising, and running. There are some books that I listen to repeatedly. I am particularly interested in the development of artificial intelligence given its significant implementations for the future of humanity.

I also enjoy physical exercise. Since middle school, influenced by my older brother, I have developed a habit of running, which I have maintained to this day. I run three times a week, covering 8 kilometers each time. During my tenure as the president of Shanghai Jiao Tong University, I also enjoyed participating in various extracurricular activities with students. Chatting with them as a peer, I felt the vigor and vitality of youth in them.