

Impurity Radiation and Transport in Wendelstein 7-X

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1 Background

Fusion is a process in which atomic nuclei combine to form a heavier nucleus, releasing a large amount of energy in the process. This process is the same as that which powers the sun and other stars in the universe. Achieving controlled fusion on Earth has been a long-standing scientific and technological challenge, with the potential to provide a virtually limitless source of clean energy.

Fusion devices are machines designed to confine and control fusion reactions. There are several types of fusion devices, including tokamaks, stellarators, and inertial confinement devices. Tokamaks are the most widely used type of fusion device, but they are known to suffer from certain instabilities that can limit their performance. Stellarators, on the other hand, are designed to be more stable, but they are typically more complex and difficult to build.

The Wendelstein 7-X is a stellarator fusion device located at the Max Planck Institute for Plasma Physics in Greifswald, Germany. It is one of the largest and most advanced stellarators in the world, with a toroidal magnetic field strength of up to 3 tesla and the ability to produce plasma with temperatures of up to 100 million degrees Celsius [?]. The Wendelstein 7-X is designed to study plasma physics and to investigate the feasibility of fusion as a future energy source.

2 Impurity Radiation

In fusion devices, impurities refer to any element other than the fuel ions (typically deuterium and tritium) that make up the plasma. Impurities can be introduced into the plasma through a variety of mechanisms, such as wall erosion, gas puffing, or injection of impurity ions.

Impurities can have a significant impact on plasma confinement, primarily through their radiation properties. When impurities are ionized in the plasma, they can emit radiation in the form of photons, which can carry away energy from the plasma and cool it down. This effect is particularly pronounced for heavy impurities such as tungsten or molybdenum, which have strong radiation lines in the visible and ultraviolet range.

The loss of energy due to impurity radiation can lead to a reduction in the plasma temperature and density, and ultimately to a decrease in the fusion reaction rate. Furthermore, impurity radiation can also cause a disruption in the plasma, leading to the loss of confinement and potentially damaging the device.

Therefore, understanding and controlling impurity radiation is crucial for achieving high-performance fusion in stellarators such as the Wendelstein 7-X. This requires detailed measurements and modeling of impurity behavior.

3 Impurity Transport

In addition to impurity radiation, impurities in fusion devices can also affect plasma confinement through their transport properties. Impurities can be transported by various mechanisms, including convection, diffusion, and drift.

One of the most significant mechanisms for impurity transport in fusion devices is neoclassical transport, which is caused by the interaction between impurities and the plasma background. Neoclassical transport can lead to the accumulation of impurities in certain regions of the plasma, which can then enhance impurity radiation and potentially disrupt plasma confinement.

Another important mechanism for impurity transport is turbulent transport, which is caused by fluctuations in the plasma density and temperature. Turbulent transport can lead to the mixing of impurities and fuel ions, which can affect the plasma properties and lead to enhanced impurity radiation.

Understanding and controlling impurity transport is also essential for

achieving high-performance fusion in stellarators such as the Wendelstein 7-X. This requires a detailed understanding of the mechanisms of impurity transport and the development of techniques for controlling impurity behavior.

4 Conclusion

Impurity radiation and transport are critical issues in fusion devices, including the Wendelstein 7-X. Impurities can affect plasma confinement and lead to a reduction in fusion performance. Therefore, detailed measurements and modeling of impurity behavior are necessary for achieving high-performance fusion in stellarators.

In particular, controlling impurity radiation and transport is essential for optimizing plasma confinement and enhancing fusion performance in the Wendelstein 7-X. This requires a comprehensive understanding of the mechanisms of impurity behavior and the development of techniques for controlling impurity transport and radiation.

Overall, the study of impurity radiation and transport in fusion devices is an essential area of research for advancing the development of fusion energy as a future source of clean, sustainable energy. The Wendelstein 7-X is a valuable tool for studying these issues and for exploring the potential of stellarator fusion as a viable energy source.