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The Direct Optimization Framework in Stellarator Design: Transport and Turbulence Optimization

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When it comes to magnetic confinement nuclear fusion, high-quality magnetic fields are crucial for sustaining high-heat plasmas and managing plasma density, fast particles, and turbulence. Transport and turbulence are particularly important factors in this process. Traditional designs of stellarator machines, like those seen in the HSX and W7-X experiments, typically optimize magnetic fields and coils separately. This approach can result in limited engineering tolerances and often overlooks turbulent transport during the optimization process. Moreover, the process is highly dependent on the initial conditions, requiring multiple restarts with relaxed requirements, which can make it inefficient and compromise the optimal balance between alpha particles, neoclassical transport, and turbulence. However, recent breakthroughs in the optimization of stellarator devices are able to overcome such barriers. Direct near-axis designs, integrated plasma-coil optimization algorithms, precise quasisymmetric and quasi-isodynamic fields, and direct turbulence optimization are among the innovations that are revolutionizing the way these machines are designed. By taking into account transport and turbulence from the start, these advancements allow for more efficient fusion devices and greater control over the plasma. In this presentation, we will discuss the main outcomes of these advancements and the prospects for even more efficient and effective fusion devices.

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