Contribution ID: **166** Type: **Parallel Sessions**

Progress toward spin-polarized fusion: Performance of laser-polarized He-3 during permeation into tokamak pellets

Wednesday, 12 September 2018 17:30 (25 minutes)

The possibility of spin-polarized fusion was introduced a few decades ago with the promise of a 50 % boost in the fusion cross section between Deuterium (D) and Tritium (T) in reaction D + T ⟶ He-5 ⟶ α + n. The same enhancement is expected in the isospin-mirrored fusion reaction, D + He-3 ⟶ Li-5 ⟶ α + p. This increase occurs if both nuclei fuse when their spins are parallel –i.e. fully polarized along the local magnetic field. However, to date, demonstration of spin polarized fusion in a tokamak reactor has not yet been carried out due to several logistical challenges. In particular, delivering polarized fuels to the plasma core has lacked a suitable method for encapsulating the fuel for tokamak injection. A multi-center collaboration, including Jefferson Lab, University of Virginia, and DIII-D/General Atomics, is planning the first direct test in the DIII-D tokamak in San Diego, using the mirror reaction D + He-3 ⟶ α + p. This proof-of-principle experiment would use inertial confinement fusion (ICF) pellets containing either polarized D (in the form of solid HD) or polarized He-3, which would be injected directly into the plasma core. The polymer shell ICF pellets can be filled by permeation at high temperatures and sealed by cooling. Deuterium can be permeated through the shell wall and then polarized using standard nuclear physics protocols; however, loading the pellet with polarized He-3 is more challenging, since He-3 must be polarized first (e.g. by spin-exchange optical pumping) and then permeated through the shell wall. Permeating He-3 is inherently prone to depolarization mechanisms such as collisions with the material of the pellet wall. Once permeated, it naturally decays to its thermal equilibrium polarization level with spin-relaxation time constant T1. He-3 must have sufficiently long T1 within the shell to allow for a practical injection sequence.

Previously, we presented preliminary results on performance of spin-polarized He-3 permeation through the ICF pellets as well as survival rate of the polarization inside the pellet. In this talk, we present recent advancements in optimizing permeation and polarization survival rate, using magnetic resonance imaging in a clinical 1.5T scanner. A 0.5-mm spatial resolution, which is sufficient for resolving the 2-mm diameter pellets used in this study, was achieved by using specially designed RF coils and chemical shift imaging (CSI) MRI pulse sequences. CSI is ideal for separately measuring signals generated by He-3 inside and outside the pellet. The presence of the pellet creates magnetic susceptibility-induced off-resonance effects such that gas inside the pellet has a slightly different precession frequency as compared to the gas outside, which enables us to track their relative concentrations over time independently. This allows us to extract two critical parameters: polarization loss during permeation and lifetime (T1) of polarized He-3 inside the pellet. We have found that the polarization loss during permeation depends on pellet wall thickness; the thinner the pellet wall, the higher polarization transfer success rate, as polarized He-3 nuclei face fewer depolarizing influences within the pellet material while permeating. For pellets with wall thickness of 15 μm, we are able to retain 91 +/- 10% of the polarization during the permeation process, and T1 = 35 +/- 7 minutes inside the pellet at room temperature. The polarization survival drops to ~ 65% in pellets with 26 μm wall thickness.

- Work supported by UVa's College of Arts and Sciences faculty research initiative seed fund, and U.S. Department of Energy contract DE-AC05-060R23177 under which Jefferson Science Associates, LLC, operates Jefferson Lab.

Primary author: Mr TAFTI, Sina (University of Virginia)

Co-authors: Dr DEUR, Alexandre (Jefferson Lab); Dr SANDORFI, Andrew M. (Jefferson Lab); Dr MILLER, G. Wilson (University of Virginia); Dr LIU, Jie (University of Virginia); Mr WEI, Kevin (University of Connecticut); LOWRY, Michael (Jefferson Lab); Dr WEI, Xiangdong (Jefferson Lab); Dr ZHENG, Xiaochao (University of Virginia)

Presenter: Mr TAFTI, Sina (University of Virginia)

Session Classification: Application of Nuclear Polarization Techniques to Other Fields

Track Classification: Application of Nuclear Polarization Techniques to Other Fields