Guide-coating facility for the TUCAN EDM experiment

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They transport UCNs from the source to the experimental setup.

Statistical Uncertainty:

\[ \sigma_{d_n} \propto \frac{1}{\sqrt{N}} \]
Ultracold Neutrons (UCN)

Neutrons that are moving so slowly that they bounce off surfaces and can be bottled.

Ultracold neutrons (UCNs) have very low energies, below 300 \(\text{neV}\). At such low energies, they are affected by magnetic, gravitational, and material potentials—strong force, that can be achieved in a laboratory environment.

- \(\nu < 8 \text{ m/s} = 30 \text{ km/h}\)
- \(T < 4 \text{ mK} (-273.15 \degree C)\)
- \(\text{K.E.} < 300 \text{ neV}\)
Graph of loss per bounce versus fermi potential

Fermi (Material) Potential

\[ V = \frac{2\pi\hbar^2}{m} N b \]

UCN flux \( \propto (V)^{3/2} \)

where,
V- Fermi potential
m- mass of the neutron
N- No. density of nuclei of material (no. of nuclei/unit vol.)
b- scattering length (strength of interaction between neutron & material nuclei
UCN flux- No. of UCNs/unit area/unit time
Pulsed Laser Deposition Facility at University of Winnipeg
Excimer laser 248nm

- HV discharge creates meta-stable KrF dimer.

- A KrF dimer relaxes, emitting a UV photon which stimulates the other dimers to emit a UV photon too.

- Produces \(~1\) J/pulse of 248 nm light.

Real carbon plasma plume
Tube coating chamber

Translation: linear bearings/shafts
Rotation: Chain driven rotational bearing

Carriage system

Front carriage

Back carriage
Some DLC coated samples

Various parts that can be coated:

<table>
<thead>
<tr>
<th>Part</th>
<th>Description</th>
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<tbody>
<tr>
<td>Tubes</td>
<td>~1”-9” inner diameters/ ~1m long</td>
</tr>
<tr>
<td>Rods</td>
<td>¼ and ½” outer diameters/ ~1m long</td>
</tr>
<tr>
<td>Plates</td>
<td>~5” discs to (30” dia. a year from now)</td>
</tr>
</tbody>
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Aluminum (left) and Copper (right) DLC-coated samples

1 m long DLC coated quartz tube

Train of DLC-coated Al tubes
Video of DLC coating - Al tube
Coating analysis

<table>
<thead>
<tr>
<th>Film Property</th>
<th>Surface Science Technique</th>
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<tbody>
<tr>
<td>Thickness</td>
<td>Profilometry, Ellipsometry, Depth profiles</td>
</tr>
<tr>
<td>Density/Fermi Potential</td>
<td>SANS, XPS, XRR</td>
</tr>
<tr>
<td>Elemental composition</td>
<td>XPS, SEM-EDS</td>
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<tr>
<td>Surface roughness</td>
<td>AFM, 2D profilometry</td>
</tr>
</tbody>
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- We use a stylus profilometer to measure the thickness and surface roughness of the DLC coatings accurately.
- The TUCAN EDM experiment needs DLC films that are > 150 nm.
- Basheer Algohi will be talking XPS analysis on Tuesday in the poster session.
Status and Future

-2024 Summer — Optimize DLC on Aluminum:
  Multilayer coating: Chromium (Cr) then DLC- for better adhesion, vary laser energy on target (spot size and laser energy), collimate parts of the ablation plume, etc.

-Fall 2024: produced several 1 m long DLC coated tubes.

-Winter/Spring 2024: Test with UCN at JPARC or TRIUMF.

-Goal to be in UCN Guide production for TRIUMF in 2025.
Collaboration meeting at University of Winnipeg, Feb 2024
Thank you!

Guide Coating Facility is open for Collaboration and providing coatings for your experiment-

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Ultracold Neutron Interactions

UCN ~ kinetic energy < 350 neV / wavelength > 50 nm / velocity < 8 m/s

• Gravity \( V_g = mgh \approx 100\text{neV} \) per meter

• Weak interaction \( n \Rightarrow p + e + \bar{\nu}_e, 782\text{keV} \)
  – beta decay

• Magnetic interaction \( V_m = -\mu \cdot B = \pm 60\text{neV} \) per Telsa
  – Changing magnetic field \( \Rightarrow F_m = -\nabla V_m = \nabla [\mu \cdot B] \)

Strong interaction responsible for UCN reflection

Can store/transport UCN on times comparable to their lifetime
The TUCAN EDM experiment needs DLC films that are > 150 nm.

From 1st yr quantum mechanics:
UCNs have very low kinetic energy, so they are very sensitive to potential barriers. DLC coating acts like a potential barrier.

DLC thickness greater than 150 nm ensures-
-Neutrons don't tunnel through the barrier (keeping more neutrons contained)

-The potential barrier is high enough to keep the neutrons trapped.