Exploration towards instrumentation systems taking advantage of optical and visual sensing

- **Visual instrumentation performance in optically-transparent conditions using TRIGA as a surrogate environment**
- **Optical properties of LiF salts and water are similar**
- **Local in-vessel phenomena resolution, identification and characterization**
- **Reconstruction of in-vessel conditions and features**

**Cherenkov Reactor Power Density Monitor:**
The electron flux in a coolant channel is closely correlated to the fission rate density in the surrounding fuel pins. The Cherenkov light detected above a coolant channel from the channel is a function of the spatial and energy dependent electron flux within the channel. Correlations can be generated to relate the electron flux in a channel to the measurable Cherenkov flux above it, allowing whole core models to be run without computationally expensive Cherenkov photons. This can be done for any coolant channel design. A 2D map of the Cherenkov flux above the core is an approximate map of the power density within the core, the precision is tied to the mean free path of gammas in the core. This can be measured by a detector placed meters away from the core.

**Detecting reactor perturbations:**
The Cherenkov spatial power monitoring method is analyzed for its ability to easily distinguish changes in the reactor state that shift the flux without changing the total reactor power. A difference plot comparing a reactor state to a baseline state allows increases or decreases in the local power level to be identified.

**Potential uses of flux tilt information:**
Downward axial flux tilts caused by partially inserted control rods are apparent. Withdrawing a peripheral rod shifts local flux tilt up. Changing reflector to graphite doesn’t change flux tilt. Blockage of coolant channel by an opaque object creates a huge upwards flux tilt in the blocked channel. The change in the total Cherenkov and in the axial tilt can be used to estimate the axial location of the block.

**Modeling:**
The MCNP is being used to model the TRIGA reactor at the Texas A&M Nuclear Science Center as a surrogate for any reactor with an optically transparent coolant. MCNP6.1.1 Beta is being used to model the reactor and the production of Cherenkov radiation from the electrons produced from fission. MCNP6.1.1 Beta is the first version of MCNP to incorporate photon transport for energies down to 1 eV and thus including visible light.

**3D: Axial flux tilts:**
A laterally offset point above a channel can be compared to the point above the channel to gain information about the axial tilt of the flux around that channel. 2D maps of the axial tilt, or change in the tilt can be created.

**Summary:**
- Visual Instrumentation in Emulated Prototypic Conditions
- Optical Instrumentation to Reconstruct and Identify Local In-Vessel Phenomena
- 2D power maps with up to pin level resolution
- 3D power profile information through a 2D map of axial flux tilts

This research effort is part of the DOE FHR-IRP team effort led by Georgia Tech on Integrated Approach to FHR Technology and Licensing Challenges led by Dr. Farzad Rahnema.

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**Usability in FHR:**
The optical properties of LiF salt, BeF₂ salt and water are similar though not identical. LiFBe salt optical properties are still unknown. The coolant channels in the FHR are closer to the rectangular approximation than in a TRIGA. Clear line of sight from core to detector is still needed.

**R&D Scope**
- Cherenkov light modeling and detection points
- 2D power profile reconstruction
- 3D extrapolation and axial flux tilt determination
- Reactor state change detection and identification

**Figure:**
- 2D map of the Cerenkov flux above the core is an approximate map of the power density within the core, the precision is tied to the mean free path of gammas in the core. This can be measured by a detector placed meters away from the core.