Defense Nuclear Nonproliferation Research & Development

Consortium for Verification Technology
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LBNL Research Highlights
LBNL POC to CVT: John Valentine
Assessing impact of monoenergetic photon sources on nonproliferation applications

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• Goals
  – Identify a broad range of applications where Monoenergetic Photon Sources (MPS) may have a high impact and prioritize.
  – Assess application requirements (system capabilities and CONOPS constraints), current capabilities, and gaps.
  – Derive photon source requirements (e.g., energy, energy spread, divergence, intensity)

• Applications selected for detailed modeling/assessment:
  – Screening and interdiction – cargo containers, trucks (lead: LLNL)
  – Detection of hidden SNM – single-sided inspection (lead: INL)
  – Warhead/dismantlement verification (lead: PNNL)
    ▪ Related: tomography for Stockpile Stewardship
  – Spent nuclear fuel dry-storage cask verification (lead: LBNL, UM)
Safeguards dry-storage cask verification
Large, shielded cask must be penetrated

- Re-verification of cask content (missing fuel bundles) by MPS transmission measurements
  - Scattering and attenuation severe
  - Pencil beam reduces scatter contribution
  - Fuel background mitigated by gating detector with MPS
  - Infrequent need – long measurement times acceptable

- **Dry-storage cask designs vary:** thick steel casks, steel storage canister in concrete overpack or in storage module, large and small fuel bundles (assemblies)

![Diagram of NUHOMS EOS (Areva TN) horizontal storage modules](image)

- Steel canister, 1.3 cm
- Concrete wall, 68 cm thick
- HI-STORM 100

![Diagram of HI-STORM 100](image)

- Overall Length: 197 to 225 in.
- Loaded Weight: 305,000 lbs.
- Typical Payload: 24 MW reactor bundles
• Longitudinal transmission scan can verify assembly occupancy
  – Short measurement time per spot
    ▪ At $3 \times 10^8$ photons/pulse, 1 kHz, $10^{-8}$ transmission → 3000 photons/s
  – Missing single pin detectable with narrow divergence beam (3.5 mrad)

Transmission probabilities
(MC-10 cask, MCNP simulations)
- No assembly: $1.4 \times 10^{-6}$
- Centered on gap: $7.6 \times 10^{-7}$
- Centered on pin: $4.5 \times 10^{-10}$
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Safeguards dry cask verification

**MPS enables transverse transmission scan**

- **Transmission calculated analytically**
  - Check against MCNP simulations shows good agreement
  - Several scans angles and cask types evaluated

- **Missing assemblies can be detected:**
  - ~10x higher transmission
  - Transmission > 10^{-12} if assembly missing
  - At 10^{-12} transmission, 3x10^8 photons/pulse, 10 kHz → 3 photons/s
  - Acceptable measurement times

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![Graph: Transmission values for 90 beams](image1)

HI-STORM MPC 24

Transmission values for 90 beams (Analytical & MCNP)

Line #

- 10^{-6}
- 10^{-9}
- 10^{-12}

![Graph: Transmission values for 90 beams](image2)

HI-STORM MPC 68

Transmission values for 90 beams (Analytical calc.)

Line #

- 10^{-6}
- 10^{-9}
- 10^{-12}

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General Conclusions

• MPS with narrow energy and angular spreads, and high rep rate will provide strong benefits for assessed applications
  – Quantitative simulations detail source needs
  – Simulations are being finalized and reported

• Selectable energy (1 – 15 MeV) at moderate 10-50% energy spread
  – Lower radiography dose, higher materials contrast
  – High photofission yield without interfering activation

• Energy spread $\leq 2\%$ enables NRF in treaty verification, cargo screening
  – $\Delta E_\gamma \sim<0.1$ would enable nuclear materials assay (safeguards)

• Narrow ‘pencil’ beam (~mrad divergence) a strong benefit:
  – Scatter rejection in radiography, higher contrast & lower doses
  – Transmission measurements on massive objects, e.g. dry-storage casks
  – Pixel-by-pixel dose adaptation in radiography
  – High flux on target for strong photofission signature

• Flux range $10^9$-$10^{12}$ photons/sec, rep rate range kHz to 10s of kHz

• Additional signatures (e.g. backscatter) identified, could increase impact
Additional Studies

• Localization of shielding volume essential for demonstrating absence of SNM in single-sided inspection scenarios
  – No detectable fission signature is not sufficient
  – Backscatter imaging appears workable with pulsed MPS

• MPS-enabled fissile-fertile discrimination techniques
  – Polarized photofission: specific, and requires less stringent MPS energy spread than NRF

• Low-Z material identification for contraband/explosive detection:
  – NRF or photoneutron techniques

• 3D resolution of objects within complex structures (e.g. cargo)
  – Voxelization & backscatter applicable – MPS reduces dose

• High resolution tomography
  – Enabled by MPS with micron-scale photon emission spot size
  – Potential for improved imaging of warheads for stockpile stewardship and intrinsic unique identification for treaty verification