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# *Tunable Diode Laser Spectroscopy (TDLS) in International Safeguards*

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# International Safeguards

- **Non-Proliferation Treaty (NPT) - Signed in 1968**
  - **Cover treaty for all non-proliferation and safeguards activities today**
- **International Safeguards under the NPT**
  - **Efforts to verify declarations made by States about their civil nuclear energy programs.**
  - **Verification of the correctness: Deterrence by detection (Traditional Safeguards – TS)**
    - **Containment and Surveillance**
    - **Non Destructive Assay**
  - **Verification of the completeness: Detection of undeclared activities (Additional Protocol – AP)**
    - **Complementary Access inspections**
    - **Satellite Imagery**
    - **Nuclear Forensics**
    - **Environmental Sampling**
    - **Open Source Analysis**
    - **And … future tools**
- **In order to answer to specific verifications objectives, safeguards measures are selected carefully and Integrated Safeguards (IS) is the current target of the IAEA to achieve the most effective and efficient combination of all safeguards measures.**
- **To support their safeguards mission, IAEA inspectors are using a broad range of instrumentation (attended, unattended, or remote).**
- **The IAEA is constantly looking to enhance its verification capabilities by upgrading existing technologies and investigating new and novel verification and detection tools for current and future safeguards activities.**

# A New Safeguards Tool: Tunable Diode Laser Spectroscopy (TDLS)

- **Promising R&D conducted to look into the applicability of TDLS-based systems toward the analysis of materials involved in nuclear fuel cycle processes.**
- **TDLS-based detection systems apply diode lasers tuned to investigate specific spectral regions.**
- **Detects molecules in an air sample, already applied for many molecules.**
- **Safeguards Interest: Identifies presence of gas signatures associated with nuclear fuel process (HF/HTO/HDO) and isotopic measurement (percentage of $UF_6$ enrichment).**
- **Advantages for Safeguards:**
  - Non-invasive method
  - In-situ with real-time data processing
- **Various envisioned applications of TDLS in different fields of potential use.**

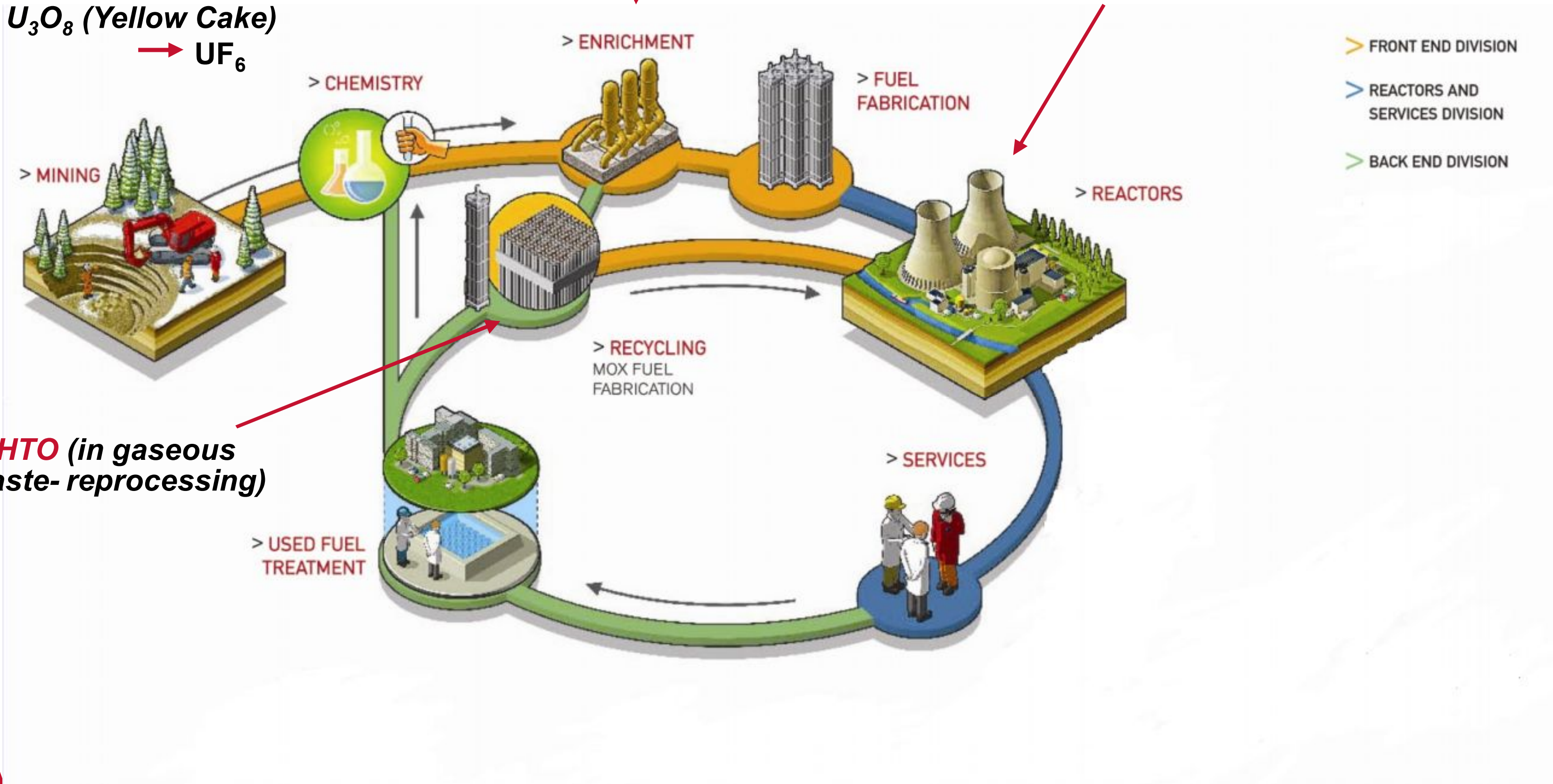
# Nuclear Fuel Cycle: Gas Signatures for TDLS

*$UF_6$ (enrichment)*

*$UF_6 + 2H_2O \Rightarrow UF_2O_2$ (s) + 4HF (g)*

*HDO (heavy water production plant)*

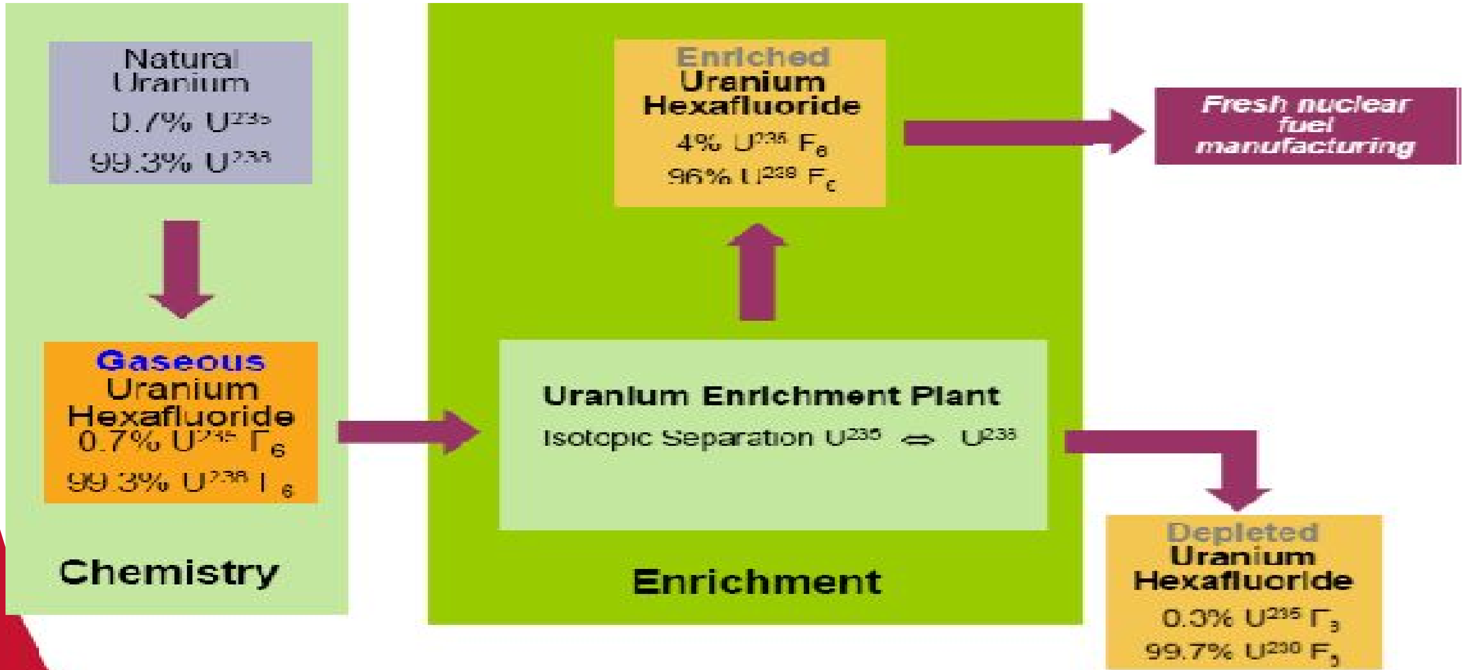
*$U_3O_8$ (Yellow Cake) → $UF_6$*




*HTO (in gaseous waste- reprocessing)*

# Monitoring Uranium Enrichment Levels

- **Only gaseous form of Uranium: $UF_6$**
- **$UF_6$ used in the nuclear industry to separate U-235 from U-238 during enrichment**
- **Natural $UF_6$ must be enriched in the fissionable isotope (U-235) to be used as nuclear fuel**
- **Different levels of enrichment are required for particular nuclear applications (civil vs. military)**
- **Monitoring of isotopic concentration important during enrichment and during periodic verification of stored $UF_6$**
  - IAEA measures enrichment of $UF_6$ stocks as indicator of weapons production
  - Safeguards methodology imposes high accuracy requirement for this type of measurement





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# *From Novel Technique to Inspector Instrument (1/2)*

- **Technical Meeting on "*Application of Laser Spectrometry Techniques in IAEA Safeguards*" in 2006 within the IAEA *Novel Techniques and Instruments for Detection of Undeclared Nuclear Facilities, Materials and Activities* project.**
  - Current TDLS project for IAEA safeguards is based on the conclusions of this technical meeting.
  - Staff and experts evaluated verification and detection approaches utilizing laser-based techniques and tasks were identified for the development of TDLS-based systems.
  - A Working Group (WG) was created to further study possible laser spectroscopy safeguards applications and to better coordinate future instruments' development.
- **Working Group (WG) for the Implementation of TDLS for IAEA Safeguards.**
  - Comprised of members actively involved in the R&D of TDLS (GPI, Connecticut College, University of Oklahoma…), commercialization of Safeguards instrumentation (CANBERRA), and technical support for Safeguards inspections (IAEA-SGTS).
  - Observers to the WG: Laser Components, CEA, European Commission, Rice University.
  - Meets on a regular basis to review the progress of projects as identified.
  - Oversees the project progress, defines milestones, accepts deliverables, and reviews requirements for new TDLS applications.
  - Provides annual report to the IAEA-SGTS director.

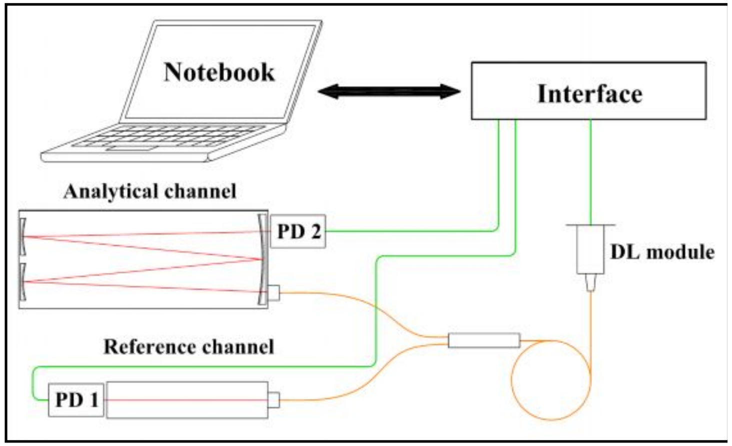
# From Novel Technique to Inspector Instrument (2/2)

- **Objectives of the WG:** To provide the IAEA with expert advice and reliable verification technique for SG purposes based on TDLS.
- **Different studying fields of potential use of TDLS-based instruments:**
  1. On-site ambient air monitoring for gas signature traces detection: HF gas monitoring system (HFLS)
  2. On-site non-destructive analysis of $UF_6$ samples (to replace current TS tools): UF6 enrichment measurement system (UFLS)
  3. Any other possible areas of use TDLS for safeguards applications.
- **Technical consideration for the implementation of safeguards specific instruments:**
  - Attended instruments: Portable, easy to operate, battery powered.
  - Unattended instruments: Development of room temperature laser, alternative would be to have non-liquid nitrogen detector.
  - High accuracy required for the measurement of the isotopic ratio: Importance of the DL spectral range etc.
  - Prototype testing: Need to establish a baseline/ test procedure to interpret the results obtained by the instrument.

# On-site Ambient Air Detector for Gas Signature Traces Monitoring: HF gas monitoring system (HFLS)

## Field of use

- Measures local concentration of HF molecule in atmosphere by its resonance absorption as an evidence of undeclared activities/facility.
- Checks the absence of HF as evidence of absence of operation involving UF6.
- Detects predominantly gaseous signatures emanating from undeclared nuclear processes (AP):
  $UF_6 + 2H_2O \Rightarrow UF_2O_2\,(s) + 4HF\,(g)$




HFLS General Scheme

## Status of development

- HF detector prototype (GPI) was demonstrated at IAEA in October 2006.
- HF detector prototype was built (CANBERRA) into a portable backpack designed for indoor and outdoor use ready for field testing.
- Calibration and sensitivity tests at Kurchatov Institute in March 2008.
- French Support Program task: Field test and comparison tests in 2008.

Instrument view

## To be discussed within the next WG meeting:

- Authorization of the HFLS for IAEA use
- Review of the HFLS User Requirements
- Manufacturing of HFLS systems for IAEA inspectors

## Challenges

- Mechanical design: weight concerns
- IAEA technical specifications: first of its kind
- Quantitative analysis of presence of HF gas in atmosphere for enrichment plant: no reference data

# On-site non-destructive analysis of $UF_6$ samples: UF6 enrichment measurement system (UFLS)

- **Field of use**
  - **Facility resident instrument for quantitative assay of U enrichment at the facility as a replacement of DA.**

- **Status of development**
  - **Prototype was developed (GPI). Proof of principle is achieved.**
  - **Real measurements observed at Kurchatov Institute in November 2007 with accuracy matching the need (replacement of DA).**
  - **IAEA service contracts to mature the scientific development with the goal of reaching readiness for industrialization (Optimization of gas handling line, Vacuum system for Laser and Detectors, optical scheme, Sample taking procedure)**
  - **"Laser Components" under GER SP task will provide 6 TDLs with wider single-mode tuning range mid-2008 to be integrated into an optimized configuration.**

- **To be discussed within the next WG meeting**
  - **Upgrading and testing the prototype detector at Kurchatov Institute**
  - **Testing of new "Laser Components" lasers**
  - **Testing of the current UFLS with QCL**
  - **Review of the UFLS User requirements**
  - **Industrialization of the UFLS system**

- **Challenges**
  - **Many.**

# TDLS in International Safeguards: How to Make it a Reality?

- 2007: a lot of progress taking TDLS from a emerging technology towards inspector instrument.
- Speed and success dependant upon founding support and involvement of experts.
- Proceed with and strengthen the efforts of the WG for the implementation of TDLS for IAEA safeguards.
- Involve R&D institutions and operators to adjust the requirements for the detector and facilitate the testing and the calibration of the devices.
- Meeting in Moscow in March 2008 is a critical step forward; strong attendance is encouraging.
- Tentative next meeting: Vienna, September 2008.

**This is work in progress –**

**Further updates will be presented**