IAEA
International Atomic Energy Agency

# The IAEA e-learning course on Neutron Imaging

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Neutron imaging in the world

Application	Number of RR	Number of MSs
Education & Training	165	52
NAA	120	52
Radioisotope production	89	42
Neutron radiography	75	39
Material/fuel test/irradiations	74	27
Neutron scattering	48	30
Geochronology	25	22
Si doping	25	17
Gem coloration	21	13
Nuclear energy research	18	10
Neutron Therapy	16	12
Nuclear Data Measurements	14	7
Other	124	36
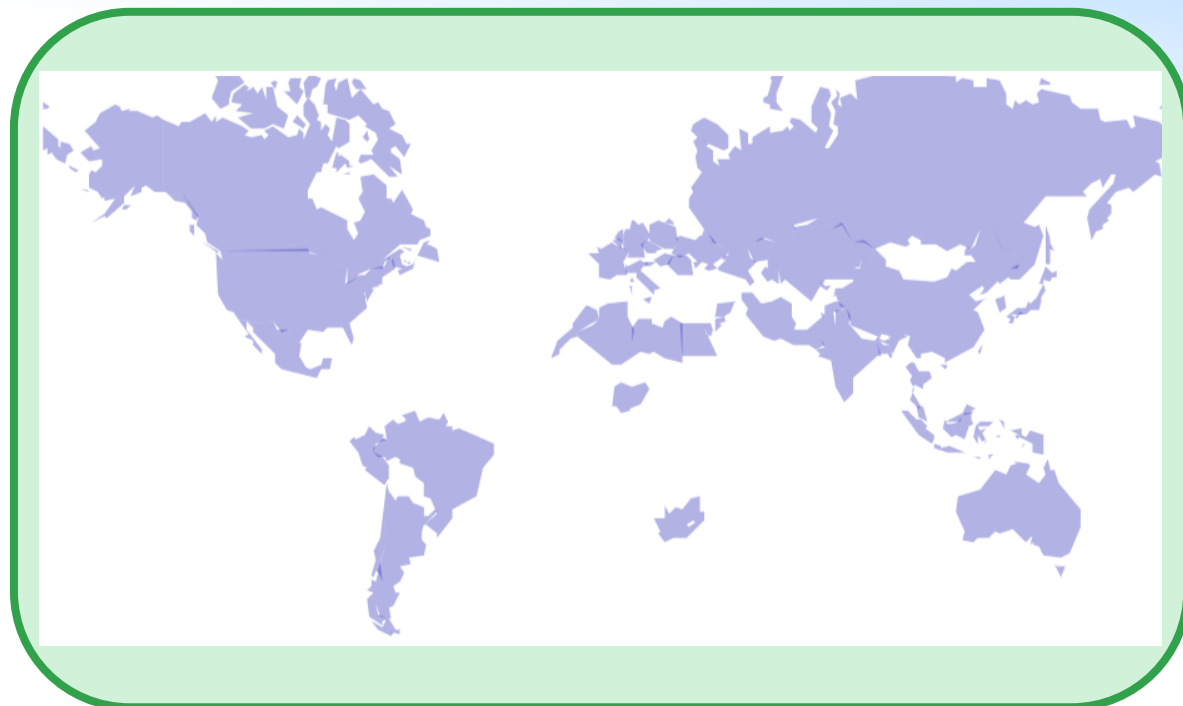
Imaging facilities, Research Reactor Database, May 2021
https://nucleus.iaea.org/RRDB/

Wide variability in capability:

- Level 1: ≈15 top facilities
- Level 2: ≈12 facilities under development or upgrade
- Level 3: A number of facilities with basic capability

Target audience

- ✓ **Young specialists or beginners who do not have sufficient experience of conducting experiments independently;**

- ✓ Experienced practitioners who want to implement or use another variety of NI;

- ✓ Professional technicians and analysts;

- ✓ Users of NI and other stakeholders who wish to understand the techniques better;

- ✓ Professors teaching nuclear sciences and applications & nuclear analytical techniques;

- ✓ Undergraduate and graduate students interested in nuclear sciences and applications & nuclear analytical techniques.

E-Learning at the IAEA

- ✓ Nuclear Technology & Applications
  - ✓ **Neutron Activation Analysis**
  - ✓ **NATs for Forensic Sciences**
  - ✓ **Strategic Planning**
  - ✓ **…**

RR e-learning courses available

- ✓ **E-learning on Neutron Imaging**
  https://elearning.iaea.org/m2/course/view.php?id=633

- ✓ **E-learning on NAA**
  https://elearning.iaea.org/m2/course/view.php?id=482

- ✓ **E-learning on Nuclear Analytical Techniques for Forensic Science**
  https://elearning.iaea.org/m2/course/view.php?id=582
  Spanish version forthcoming

- ✓ **Strategic Planning for National Nuclear Institutions**
  https://elearning.iaea.org/m2/course/view.php?id=570

- ✓ **Introductory training course for research reactor personnel**
  Bilingual English and Spanish
  https://elearning.iaea.org/m2/course/index.php?categoryid=119

Neutron Imaging e-learning

✓ **Course developed within TC project RER1016**
- ✓ Advanced facilities (level 1) in Europe: source of experts
- ✓ Several other facilities in Europe: recipients of training, source of feedback

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Neutron Imaging e-learning

Activity	Milestone	Other outputs	Completion date
Phase 1: Define course structure	Course syllabus completed	Learning objectives Templates for lectures, lecture notes and exercises Self-assessment methodology Collection and organization by subject of existing materials	31 October 2017 30 topics in 6 areas
Phase 2: Develop training materials	Draft course lectures completed	Drafting course materials Draft lecture notes	9 April 2018
Phase 3: Review of training materials	Review of draft course lectures completed	Meeting report	16-18 April 2018
Phase 4: Develop revised training materials	Complete draft of e-learning course	Second draft of course lectures completed Practical exercises developed Self-assessment tests quizzes and case studies developed	30 November 2018
Phase 5: Test e-learning course	E-learning course tested	Final version of e-learning materials Meeting report	AUNIRA September 2019
Phase 6: Implementation of e-learning course	E-learning course on-line and accessible to MSs	E-learning materials converted to standard in use by the Agency E-learning course on-line and tested by main experts and reviewers	(December 2019) October 2020

Testing the course: AUNIRA 2019

Training Workshop on the Advanced Use of Neutron Imaging for Research and Applications (AUNIRA)
23–27 September 2019, Daejeon, Republic of Korea

36 participants from all regions

The e-learning course materials were used, participants provided feedback
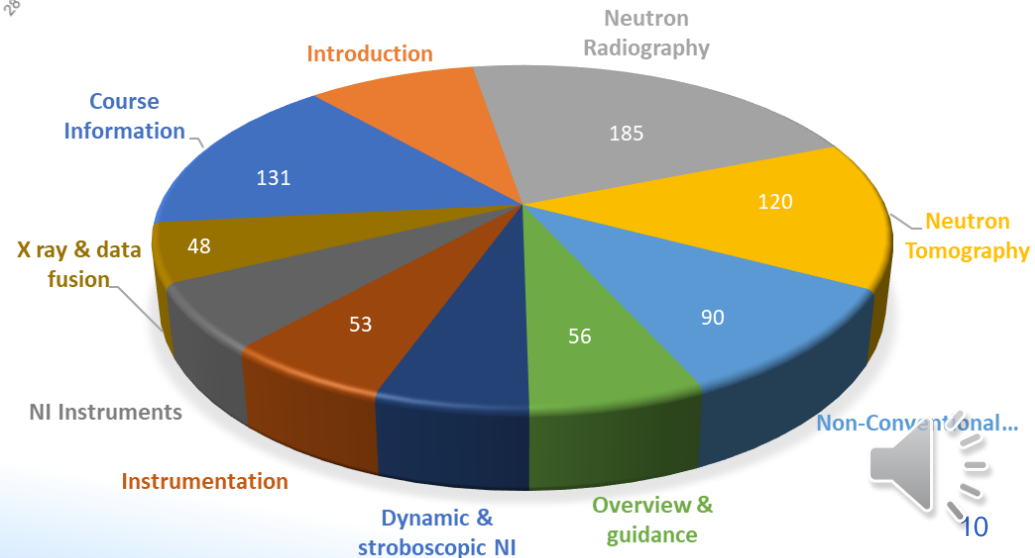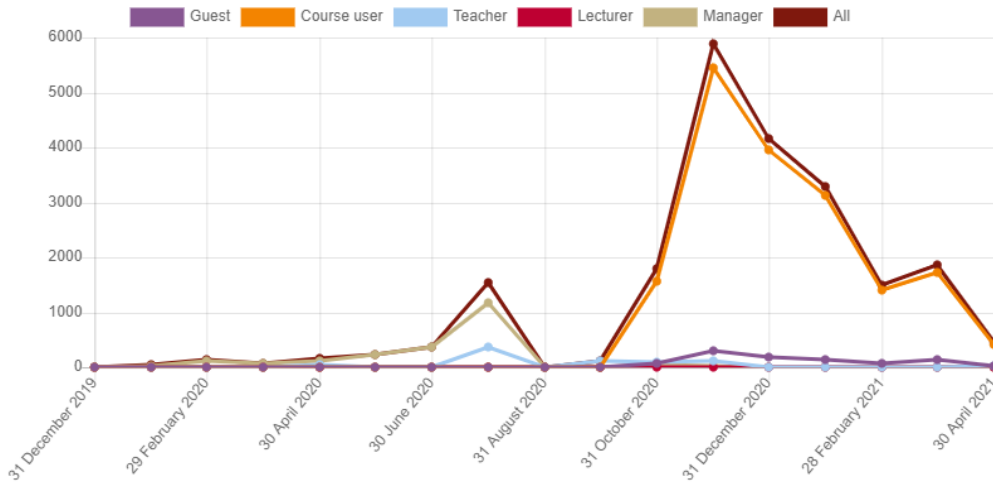
Course structure

1. General introduction

2. Neutron radiography
   - 2.1. Introduction and history
   - 2.2. Interaction of neutrons with matter
   - 2.3. Basic image parameters
   - 2.4. Image acquisition strategy
   - 2.5. Applications
   - 2.6. Limitations and developments

3. Neutron tomography
   - 3.1. General introduction and history
   - 3.2. Theoretical background
   - 3.3. Artefacts and corrections
   - 3.4. Software packages for reconstruction and visualization
   - 3.5. Examples and applications of neutron tomography

4. Non-conventional neutron imaging techniques
   - 4.1. Energy-selective imaging
   - 4.2. Diffractive neutron imaging
   - 4.3. Phase and dark-field contrast
   - 4.4. Imaging with polarized neutrons

5. Overview schema and guidance

6. Dynamic and stroboscopic neutron imaging

7. Instrumentation for neutron imaging
   - 7.1. Sources of neutron beams
   - 7.2. Beam properties
   - 7.3. Systems for neutron transport
   - 7.4. Neutron detectors
   - 7.5. Sample manipulators and infrastructure

8. Neutron imaging instrument
   - 8.1. Beam characterization
   - 8.2. Beam conditioning
   - 8.3. Detector systems
   - 8.4. Shielding and infrastructure
   - 8.5. Examples of different types of instruments

9. X-ray Imaging and data fusion

Neutron imaging e-learning usage

- ✓ **≈ 230 users** from **≈ 59 MSs**, **≈ 900 completed activities**
- ✓ Used in imaging Training Workshops

Neutron Imaging - All activity (all roles)

Legend: Guest, Course user, Teacher, Lecturer, Manager, All

Pie chart values:
- Neutron Radiography: 185
- Neutron Tomography: 120
- Non-Conventional...: 90
- Overview & guidance: 56
- Dynamic & stroboscopic NI: (not labeled)
- Instrumentation: 53
- NI Instruments: (not labeled)
- X ray & data fusion: 48
- Course Information: 131
- Introduction: (not labeled)

Developments

- ✓ Dissemination and promotion of the tool to the IAEA MSs
  - ✓ Neutron imaging email list
  - ✓ Relevant meetings & conferences

- ✓ Living tool: Periodic updates and training events
  - ✓ AUNIRA neutron imaging workshop in September: Open for nominations!
  - ✓ Further feedback from users to be incorporated
  - ✓ Experience gathered in its usage will lead to a revision in the coming years

- ✓ Similar E-learning tools for other applications of RRs and NATs

Thank you!