Module MPE04: Innovation - Advanced X-ray physics for imaging device and user protocol innovation in D&IR

ABSTRACT

Title: Innovation - Advanced X-ray physics for imaging device and user protocol innovation in D&IR

Module Code: MPE04

Module Level: EQF level 8

Aims: This module course will first present the latest research results regarding the physical principles of X-ray imaging. Furthermore, the lectures will discuss the application of new X-ray sources to diagnostic radiology. Finally, an introduction to novel imaging modalities which take advantage of energy and phase characteristics of X-ray quanta will be provided. The teaching method will consist of oral sessions and practical sessions. In the latter case, the candidates will have the opportunity to visit laboratories which host monochromatic X-ray sources and make their own experiment.

Learning Outcomes: At the end of the module the participants will be able to:

MPE04.01	Take responsibility for statutory and institutional requirements for Medical Physics Services in Diagnostic and Interventional Radiology with respect to Innovation.
MPE04.02	Research, critique and assess innovative diagnostic and interventional radiology systems based on the use of monochromatic radiation.
MPE04.03	Assess, evaluate and optimise the beam quality of X-ray imaging systems for diagnostic and interventional radiology.
MPE04.04	Assess, evaluate and optimise X-ray imaging systems for diagnostic and interventional radiology based on the use of energy dependence of X-rays (dual-energy and spectral imaging).
MPE04.05	Assess, evaluate and optimise X-ray imaging systems for diagnostic and interventional radiology based on the use of phase contrast.
MPE04.06	Take responsibility for the translation of new devices and modification of existing devices into the clinical practice.
MPE04.07	Take responsibility for statutory and institutional requirements for Medical Physics Services in Diagnostic and Interventional Radiology with respect to Scientific Problem Solving Service.
MPE04.08	Implement and evaluate strategic solutions to the challenges facing the MPE (D&IR) in own country and Europe.
MPE04.09	For each imaging modality, explain strengths and limitations and their impact on image quality / diagnostic efficacy.
MPE04.10	For each modality, operate imaging devices at the level necessary for give advice on optimization of imaging protocols, quality control, image quality manipulation, and carry out research when the available evidence for advice is not sufficient.
MPE04.11	Discuss the advantages and disadvantages of imaging as a means of displaying spatially dependent signals and variables.
MPE04.12	For each imaging modality, explain differences in device design and their effects on image quality and patient safety for dedicated devices.

Date and Location of Face-to-Face Component: **Ferrara 13th – 17th July 2015**

Module Leaders:

Dr. Angelo Taibi (angelo.taibi@unife.it)
Angelo Taibi, PhD, is Assistant Professor at the Department of Physics and Earth Sciences, University of Ferrara, and teaches applied physics at the Department of Life Sciences and Biotechnologies. His expertise covers various aspects of the physics of diagnostic radiology. He has worked for many years in the development of quasi-monochromatic X-ray sources for diagnostic radiology. Recently, he has been involved in scientific projects concerning the advanced applications of digital mammography such as dual-energy and tomosynthesis.

Prof. Mauro Gambaccini (mauro.gambaccini@unife.it)
Mauro Gambaccini, PhD, is Full Professor at the Department of Physics and Earth Sciences, University of Ferrara, and teaches Applied Physics at the Department of Life Sciences and Biotechnologies and at the Department of Chemical and Pharmaceutical Sciences. He teaches also Medical Physics at the Department of Physics and Earth Science. His expertise covers various aspects of the physics of diagnostic radiology. He has worked for many years in the development of quasi-monochromatic X-ray sources for diagnostic radiology. Recently, he has been involved in scientific projects concerning the advanced applications of digital mammography such as dual-energy using novel non-conventional X ray sources.

Faculty: Angelo Taibi, Mauro Gambaccini, Paolo Cardarelli, Renata Longo, Luigi Rigon, Giuliana Tromba, Hilde Bosmans

Delivery of the module: The module will achieve its learning objectives using a combination of online and face-to-face readings, fora, presentations and discussions. The online phase will be mostly asynchronous so that participants would not need to take time off their clinical duties and there will not be a problem with time zones. If any synchronous learning is required this would be in the evening or weekend. The face-to-face component will be over a period of 1 week (3 days learning, 1 day free for revision, 1 day for assessment).

Total participant effort time: 80 hours

Assessment Mode: The assessment mode will consist of a written closed-book examination regarding few cases scenarios of situations faced by MPE (D&IR) in which candidates are expected to demonstrate that they have a sufficient knowledge to assist radiologist and younger members of the profession and to explain to them the limits of clinical D&IR facilities in comparison with the new emerging X-ray imaging modalities. Participants are expected to back their arguments with the scientific rationale of such advanced X-ray imaging technologies. A public oral discussion will follow. In this part, examiners will evaluate the answer motivations and the input to the discussion of the other participants (opinions, corrections, different perspectives …).

MODULE DATA	
Module Homepage	www.eutempe-rx.eu
Module Code	MPE04
Module Leader/s Please limit CV to a max of 250 words and to what is relevant to this module.	Dr. Angelo Taibi Dept of Physics and Earth Sciences, University of Ferrara, Italy; Phone: +39 0532 974218; e-mail: angelo.taibi@unife.it Angelo Taibi, PhD, is Assistant Professor at the Department of Physics and Earth Sciences, University of Ferrara, and teaches applied physics at the Department of Life Sciences and Biotechnologies. His expertise covers various aspects of the physics of diagnostic radiology. He has worked for many years in the development of quasi-monochromatic X-ray sources for diagnostic radiology. Recently, he has been involved in scientific projects concerning the advanced applications of digital mammography such as dual-energy and tomosynthesis. Prof. Mauro Gambaccini Dept of Physics and Earth Sciences, University of Ferrara, Italy; Phone: +39 0532 974222; e-mail: mauro.gambaccini@unife.it Mauro Gambaccini, PhD, is Full Professor at the Department of Physics and Earth Sciences, University of Ferrara, and teaches Applied Physics at the Department of Life Sciences and Biotechnologies and at the Department of Chemical and Pharmaceutical Sciences. He teaches also Medical Physics at the Department of Physics and Earth Science. His expertise covers various aspects of the physics of diagnostic radiology. He has worked for many years in the development of quasi-monochromatic X-ray sources for diagnostic radiology. Recently, he has been involved in scientific projects concerning the advanced applications of digital mammography such as dual-energy using novel non-conventional X ray sources.
Teaching Staff Teaching staff should be either recognised MPEs or in possession of a PhD. If not please contact the Secretary of the QAC.	Dr Angelo Taibi, PhD: Module leader Prof Mauro Gambaccini PhD: Module leader Dr Paolo Cardarelli, PhD: University of Ferrara Prof Renata Longo, PhD: University of Trieste Dr Luigi Rigon, PhD: University of Trieste Dr Giuliana Tromba PhD: Coordinator of the SYRMEP project at ELETTRA synchrotron source, Trieste

<table>
<tr><td rowspan="2">Candidate Assessment
(all assessments open book)</td><td colspan="2">Written Assessment (closed-book):</td><td colspan="2">A 1-hour paper with case-study questions. No choice is allowed.</td></tr>
<tr><td colspan="2">Oral Assessment (closed-book):</td><td colspan="2">Evaluation of answer motivations and participation (opinions, corrections, different perspectives …).</td></tr>
<tr><td rowspan="2">Module Duration

The TOTAL number of hours of participant effort should be about 80. (including lectures, reading of assigned compulsory texts, participation in online fora etc)</td><td>Online phase

Asynchronous methods should be used whenever possible so that participants would not need to take time off their clinical duties and there will not be a problem with time zones. However synchronous methods (evenings or weekends only) should be used when crucial.</td><td colspan="3">The online component will be spread over a period of approximately 3 - 4 weeks and would require approximately 48 hours of reading and effort by the participants. The online phase will be mostly asynchronous so that participants would not need to take time off their clinical duties and there will not be a problem with time zones. If any synchronous learning is required this would be in the evening or weekend.</td></tr>
<tr><td>Face-to-face phase

Must include 1 day for revision and 1 day for the assessment proper.</td><td colspan="3">5 days: 3 days content delivery (22 hours), 1 day for revision, 1 day for assessment.</td></tr>
<tr><td>Date and location of Face-to-Face</td><td colspan="4">Ferrara, 13th – 17th July 2015</td></tr>
<tr><td>Date of Assessment
Normally last day of face-to-face phase.</td><td colspan="4">17th July 2015</td></tr>
<tr><td rowspan="4">Breakdown of participant effort time</td><td colspan="3">Module Component</td><td>Estimated Time</td></tr>
<tr><td colspan="3">Online lectures, seminars, tutorials, fora</td><td>10 hours</td></tr>
<tr><td colspan="3">Online compulsory reading</td><td>48 hours</td></tr>
<tr><td colspan="3">Face-to-face lectures, seminars, tutorials, fora</td><td>18 hours (over 3 days)</td></tr>
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	Face-to-face technical demonstrations	2 hours
	Face-to-face laboratory/clinical exercises	2 hours
	Total participant effort time	**80 hours**
	Free day for exam preparation day (same for all modules)	**1 day**
	1 day for assessment (same for all modules)	**1 day**

PRE-REQUISITES FOR THE MODULE	
Minimum entry qualifications, training and years of experience for *all* modules Same for all modules	EQF Level 6 in Physics (BSc Physics or equivalent) EQF Level 7 in Medical Physics (MSc Medical Physics or equivalent) 2 year equivalent clinical training in D&IR for clinical Medical Physicists 2 year equivalent Industry/Radiation Authority experience for Industry/Radiation Authority personnel.
Assumed previous KSC for *all* modules from the 'Inventory of Learning Outcomes for the MPE in Europe' (Annex I of the 'European Guidelines on the MPE') Same for all modules	GENERIC SKILLS : Generic Skills Required at EQF level 7 KSC FOR THE MPE AS PHYSICAL SCIENTIST: All Knowledge learning outcomes to EQF level 7 KSC FOR THE MPE AS A HEALTHCARE PROFESSIONAL: All Knowledge learning outcomes to EQF level 7 KSC FOR THE MPE AS EXPERT IN CLINICAL MEDICAL RADIOLOGICAL DEVICES & RADIATION PROTECTION: All Knowledge learning outcomes to EQF level 7 KSC SPECIFIC FOR THE MPE IN DIAGNOSTIC & INTERVENTIONAL RADIOLOGY: All Knowledge learning outcomes to EQF level 7 The Skills and Competences included in the IAEA document 'Clinical Training of Medical Physicists Specializing in Diagnostic Radiology' (IAEA Training Course Series, 47, 2010) to EQF level 7.
Pre-requisite EUTEMPE-RX online summary modules for *all* modules	MPE04 Development of the profession and the challenges for the MPE (D&IR) in Europe (online summary version accessible to all participants in all courses)
Additional pre-requisite EUTEMPE-RX online summary modules for *this* module Different for each module.	None required

MODULE CONTENT: AIM and SUMMARY LEARNING OUTCOMES	
Aim	This module course will first present the latest research results regarding the physical principles of X-ray imaging. Furthermore, the lectures will discuss the application of new X-ray sources to diagnostic radiology. Finally, an introduction to novel imaging modalities which take advantage of energy and phase characteristics of X-ray quanta will be provided. The teaching method will consist of oral sessions and practical sessions. In the latter case, the candidates will have the opportunity to visit laboratories which host monochromatic X-rays sources and make their own experiment.
Learning Outcomes (10 – 15 learning outcomes which provide an overview of the KSC addressed in the module)	MPE04.01 Take responsibility for statutory and institutional requirements for Medical Physics Services in Diagnostic and Interventional Radiology with respect to Innovation. MPE04.02 Research, critique and assess innovative diagnostic and interventional radiology systems based on the use of monochromatic radiation. MPE04.03 Assess, evaluate and optimise the beam quality of X-ray imaging systems for diagnostic and interventional radiology. MPE04.04 Assess, evaluate and optimise X-ray imaging systems for diagnostic and interventional radiology based on the use of energy dependence of X-rays (dual-energy and spectral imaging). MPE04.05 Assess, evaluate and optimise X-ray imaging systems for diagnostic and interventional radiology based on the use of phase contrast. MPE04.06 Take responsibility for the translation of new devices and modification of existing devices into the clinical practice. MPE04.07 Take responsibility for statutory and institutional requirements for Medical Physics Services in Diagnostic and Interventional Radiology with respect to Scientific Problem Solving Service. MPE04.08 Implement and evaluate strategic solutions to the challenges facing the MPE (D&IR) in own country and Europe. MPE04.09 For each imaging modality, explain strengths and limitations and their impact on image quality / diagnostic efficacy. MPE04.10 For each modality, operate imaging devices at the level necessary for give advice on optimization of imaging protocols, quality control, image quality manipulation, and carry out research when the available evidence for advice is not sufficient. MPE04.11 Discuss the advantages and disadvantages of imaging as a means of displaying spatially dependent signals and variables. MPE04.12 For each imaging modality, explain differences in device design and their effects on image quality and patient safety for dedicated devices.

MODULE CONTENT: TARGET KSC TO BE DEVELOPED TO EQF LEVEL 8 **From the 'Inventory of Learning Outcomes for the MPE in Europe' (Annex I of the 'European Guidelines on the MPE')**	
KSC targeted in *all* modules These learning outcomes are common to and permeate *all* modules, although to a varying degree according to the topic of the module.	GENERIC SKILLS : All 'Generic Skills Required at EQF level 8' KSC FOR THE MPE AS PHYSICAL SCIENTIST: All Skills and Competences to EQF level 8 KSC FOR THE MPE AS A HEALTHCARE PROFESSIONAL: All Skills and Competences to EQF level 8 KSC FOR THE MPE AS EXPERT IN CLINICAL MEDICAL RADIOLOGICAL DEVICES & RADIATION PROTECTION (AND OTHER PHYSICAL AGENTS AS APPROPRIATE): All KSC for Scientific Problem Solving Service to EQF level 8 KSC SPECIFIC FOR THE MPE IN DIAGNOSTIC & INTERVENTIONAL RADIOLOGY: All KSC for Scientific Problem Solving Service to EQF level 8
***PRIMARY KSC* targeted in *this* module** These are the KSC which would be developed to Level 8 during this module. These should be mostly Skills and Competences. However, Knowledge learning outcomes should also be included when the knowledge normally acquired during Level 7 programmes is insufficient for the development of the skills and competences to level 8. The KSC codes from the 'European Guidelines on the MPE' should be inserted for easy reference.	**<u>KSC FOR THE MPE AS EXPERT IN CLINICAL MEDICAL RADIOLOGICAL DEVICES & RADIATION PROTECTION (AND OTHER PHYSICAL AGENTS AS APPROPRIATE)</u>** **Scientific Problem Solving Service** K2. Use physics, concepts, principles and theories to explain in detail and quantitatively, the structure, functioning, characteristics, strengths and limitations and use of the medical devices used in own area of medical physics. K3. Explain in detail and quantitatively the properties of ionising radiations (electromagnetic, electrons, ions, neutrons) and other physical agents (e.g., electrical energy, static electric / magnetic fields, non-ionising electromagnetic radiation, vibration, sound and ultrasound, heat energy and laser) to be found in the healthcare environment. S1. Apply the general concepts, principles, theories and practices of physics to the solution of clinical problems concerning the optimised clinical use of medical devices and safety / risk management with respect to associated ionizing radiations and other physical agents. S2. Use the general concepts, principles, theories and practices of physics to analyze the research literature concerning the optimised use of medical devices and safety / risk management with respect to ionizing radiations and other associated physical agents. C3. Take responsibility for applying the general concepts, principles, theories and practices of physics to analyze the research literature concerning the optimal use of medical devices and management of risk from associated ionizing radiations and other physical agents and to transfer relevant published research results to the clinical environment in own area of medical physics practice. C4. Take responsibility for applying the general concepts, principles, theories and practices of physics to the solution of clinical problems concerning the optimal use of medical devices and management of risk from associated ionizing radiations and other physical agents in own area of medical physics practice.

C5. Take responsibility to apply the general concepts, principles, theories and practices of physics for the selection and insertion of new medical devices within own area of medical physics practice and to facilitate the effective, safe and economical use of said devices.

Innovation

K136. Explain statutory and institutional requirements for Medical Physics Services with respect to Innovation in own area of medical physics practice.
K137. Define innovation as the development of new devices (including software), modification of existing devices (including software) and the development of new techniques using devices for the solution of hitherto unresolved clinical problems.
K138. Explain the importance of ongoing horizon scanning for new and emerging technologies.
K139. Explain the methodology of horizon scanning for new and emerging technologies.
K140. Discuss the opportunities for innovation in own area of medical physics practice.

S78. Apply the methodology of horizon scanning (including survey of specific information sources) for new and emerging technologies to own area of medical physics practice.

C82. Take responsibility for statutory and institutional requirements for Medical Physics Services with respect to Innovation in own area of medical physics practice.
C83. Take responsibility for the development of new devices (including software) and modification of existing devices (including software), including their implementation and evaluation in response to clinical needs in own area of medical physics practice.
C84. Take responsibility for legal issues involved in the development of medical devices (including software) in own area of medical physics practice.

<u>KSC SPECIFIC FOR THE MPE IN DIAGNOSTIC & INTERVENTIONAL RADIOLOGY</u>

Scientific Problem Solving Service

K3. Discuss the advantages and disadvantages of imaging as a means of displaying spatially dependent signals and variables.
K11. For each imaging modality, explain sources of measurement inaccuracy, uncertainty and artefacts.
K21. For each imaging modality, explain in detail the operation, technical principles and geometry of imaging equipment.
K22. For each imaging modality, explain device design variables which impact device performance indicators (e.g., focal spot size in the case of X-ray imaging).
K23. For each imaging modality, explain user controlled variables/settings and their impact on image quality/diagnostic efficacy and patient risk.

	K24. For each imaging modality, explain strengths and limitations and their impact on image quality / diagnostic efficacy (including any artefacts). K26. For each imaging modality, explain differences in device design and their effects on image quality and patient safety for dedicated devices (e.g., mammography, dental systems for projection X-ray imaging). S1. For each modality, operate imaging devices at the level necessary for give advice on optimization of imaging protocols, quality control, image quality manipulation, and carry out research when the available evidence for advice is not sufficient. S3. Manipulate acquisition parameters for all forms of projection X-ray imaging devices (e.g., kV, filtration, mAs, sensitivity ('speed'), collimation, magnification, SID, SSD, frame rate, screening time, manual/AED modes, compression), explain the effect on image quality and relevant patient dose quantities (and occupational dose particularly when this is correlated with patient dose) and relevance to specific clinical studies. S9. Use specialised test tools e.g., contrast-detail test objects, to evaluate imaging systems. C1. Take responsibility for statutory and institutional requirements for Medical Physics Services in Diagnostic and Interventional Radiology with respect to Scientific Problem Solving Service. C2. Carry out or supervise as appropriate the measurement of physical quantities relevant to the effective, safe and economical use of medical devices / ionizing radiations and other physical agents in Diagnostic and Interventional Radiology. **Innovation in D&IR** K118. Explain statutory and institutional requirements for Medical Physics Services in Diagnostic and Interventional Radiology with respect to Innovation. C32. Take responsibility for statutory and institutional requirements for Medical Physics Services in Diagnostic and Interventional Radiology with respect to Innovation.

***SECONDARY KSC* targeted in *this* module** (EQF Level 8) These are the KSC that are included in the module but would be given less attention owing to time constraints. Please insert the KSC code from the 'European Guidelines on the MPE' project KSC Inventory.	
***NEW KSC* which are NOT** INCLUDED in the 'Inventory of Learning Outcomes for the MPE in Europe'.	<u>Knowledge</u> Research, critique and assess innovative diagnostic and interventional radiology systems based on the use of monochromatic radiation. <u>Competence</u> Take responsibility for the translation of new devices and modification of existing devices into the clinical practice.

OUTLINE TEACHING PLAN	
Online phase	The online component will consist of a series of sets of compulsory readings on the topics below. Each set will be accompanied by an asynchronous online forum for difficulties and prompting question/s to provoke reflection and discussion. An initial range of topics are: 1. Spectral Imaging: define the principles of this novel X-ray modality and explain how the use of energy spectrum can be exploited via dedicated detector technology. 2. Photon counting detectors vs integration detectors. 3. Introduction to particle accelerators technology, with particular attention to those involved in radiation production applications 4. Synchrotron radiation, wigglers and undulators, free-electron laser 5. Table top accelerators for applications in diagnostic radiology 6. Introduction to particle-laser interaction for the production of intense radiation sources (Inverse Compton, betatron radiation etc) 7. Introduction on X-ray sources based on accelerated particle interacting with crystalline structures (PXR, coherent bremsstrahlung etc) 8. Review of the state-of-the-art of the most promising X-ray sources based on particle acceleration and of some recent application with interest in diagnostic radiology 9. X-ray diffraction and X-ray energy selection using crystals 10. Quasi monochromatic sources based on conventional X-ray tubes and crystal diffraction 11. SR and other exotic sources: introduce the characteristics of such X-ray sources and the facilities that allow the production of monochromatic and intense X-ray beams. 12. Explain the imaging properties of SR and their diagnostic potential. 13. Review of main phase-contrast imaging techniques (free-propagation, gratings, crystal selectors) and current state-of-the-art 14. Phase-contrast imaging: define the meaning of phase-contrast in relationship to the well-known absorption contrast and introduce the mechanism that allows one to produce and to detect images according to this physical phenomenon. 15. The potential of phase-contrast to diagnostic radiology by means of specific applications.

Face-to- Face Phase	
	Daily sessions will be followed by a round-table discussion led by a panel of European leaders of the profession (A. Taibi, M. Gambaccini, P. Cardarelli, R. Longo, L. Rigon, G. Tromba, H. Bosmans). 1. Fundamental physics of X-rays: energy, absorption and their phase for innovation purposes (A. Taibi) 2. Spectral imaging with conventional and photon counting detectors (A. Taibi) 3. Techniques to obtain quasi monochromatic X-rays with conventional X-ray tubes (M. Gambaccini) 4. Table-top accelerators for applications in diagnostic radiology (M. Gambaccini) 5. High-brilliance X-ray sources based on particle accelerators. Part 1: Theoretical background (P. Cardarelli) 6. High-brilliance X-ray sources based on particle accelerators. Part 2: Potential applications in D&IR (P. Cardarelli) 7. Introduction to Synchrotron Radiation (G. Tromba) 8. Fundamental of Phase-Contrast Imaging (L. Rigon) 9. Diagnostic applications of Phase Contrast Imaging (R. Longo) Practical sessions to be discussed with panel of European leaders: In conventional X-ray sources, the energy of the beam is controlled by varying the kVp and/or filtration. HVL is the parameter that identifies the effective energy of X-ray beam. This parameter and the entrance exposure are generally used for the estimation of the patient dose. In the case of monochromatic or quasi-monochromatic X-ray sources, the control of the energy of the beam is carried out in a different way. The sources actually used for clinical applications are based on Bragg diffraction for which the energy selection is done by modifying the incidence of X-rays beam onto a crystal surface. Innovation in X-ray imaging for medical application also relies on the use of phase contrast, a novel technology that has the potential to improve image contrast beyond the one normally seen in present imaging systems. Session 1: Selection of the beam energy, spectrum measurement and energy resolution. Measurement of the photon fluence on the image plane with and without standard breast phantom. Session 2 Capturing monochromatic X-ray absorption radiograph and measurement of the spatial resolution Session 3 (SR facility in Trieste). Acquisition of monochromatic X-ray images to record absorption and phase contrast. Evaluation of the contribution of phase-contrast as a function of the beam energy.