The Faculty of Medicine of Harvard University
Curriculum Vitae

Date Prepared:	**January 17, 2023**
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Place of Birth:	Hannover, Germany

Education:

11/1984	Vordiplom (B.S.)	Geophysics	University of Kiel, Germany
07/1988	Diplom (M.S.)	Physics	University of Heidelberg, Germany
11/1990	Dr. rer. nat. (Ph.D.)	Physics (summa cum laude) (Wolfgang Schlegel, Josef Bille)	University of Heidelberg
07/1995	Habilitation and Venia Legendi	Physics	University of Heidelberg

Postdoctoral Training:

02/91-09/92	Research Associate (Postdoctoral Fellow)	Medical Physics (PI: Wolfgang Schlegel)	German Cancer Research Center (DKFZ), Department of Biophysics and Medical Radiation Physics
10/92-06/93	Postdoctoral Fellow	Medical Physics (PI: Arthur Boyer)	Institute of Radiation Physics, MD Anderson Cancer Center, Houston, TX
07/93-10/94	Research Associate (Postdoctoral Fellow)	Medical Physics (PI: Wolfgang Schlegel)	DKFZ, Department of Medical Physics
01/13-12/14	Physician Leadership Development Program	Massachusetts General Physicians Organization	Massachusetts General Hospital

Faculty Academic Appointments:

07/95-05/01	Privatdozent (Associate Professor)	Physics	Faculty of Physics and Astronomy, University of Heidelberg
06/01-04/08	Associate Professor	Radiation Oncology	Harvard Medical School
05/08-	Professor	Radiation Oncology	Harvard Medical School
11/17-	Honorary Professor	Faculty of Medicine	University of Freiburg, Germany
03/01/2022 –	Andres Soriano Endowed Professorship	Radiation Oncology	Harvard Medical School

Appointments at Hospitals/Affiliated Institutions:

11/94-05/96	Scientific staff member	Medical Physics	German Cancer Research Center (DKFZ)
06/96-05/01	Tenured Scientist	Medical Physics	DKFZ
06/01-05/08	Associate Radiation Biophysicist	Radiation Oncology (Radiation Biophysics)	Massachusetts General Hospital
06/08-	Radiation Biophysicist	Radiation Oncology (Radiation Biophysics)	Massachusetts General Hospital

Major Administrative Leadership Positions:

Local

1994-2001	Head of working group “Physical Models”	German Cancer Research Center
1996-2001	Deputy Head, Department of Medical Physics	German Cancer Research Center
2001-2008	Director of Physics Research	Massachusetts General Hospital (Radiation Oncology)
2008-	Chief, Division of Radiation Biophysics	Massachusetts General Hospital (Radiation Oncology)

Committee Service:

Local

1999	Steering council	Heidelberg IMRT school
1999-2001	Budget committee	German Cancer Research Center (Radiological Diagnostics and Therapy)
2001-2006	Organizer, Medical Physics seminar	Massachusetts General Hospital (Radiation Oncology)

2004-2010	Boston host of "International Master's Program in Medical Physics" of the University of Heidelberg-Mannheim	Massachusetts General Hospital (Radiation Oncology)
2006-2008	Proton beam scanning oversight committee	Massachusetts General Hospital, Radiation Oncology
2009-2013	Promotions, Reappointments, and Appointments Committee (P&R)	Harvard Medical School
2010-2011	Chair, ad hoc committee for promotion to full professor	Harvard Medical School
2012-	Chair, proton projects oversight committee	Massachusetts General Hospital, Radiation Oncology
2013-	Chair/co-chair, medical physics residency program oversight committee	Harvard Medical School
2013	Ad hoc committee for promotion to full professor	Harvard Medical School
2014-	Internal Steering Committee, Proton Program Project Grant (P01)	Massachusetts General Hospital, Radiation Oncology
2014-2017	Subcommittee of Professors: recommendations to the Dean regarding appointments at the level of full professor	Harvard Medical School
2020-	Co-chair, Promotion committee	Massachusetts General Hospital, Radiation Oncology

Regional

1995-1997	Heavy ion therapy steering committee	GSI Darmstadt, Germany

National

2013	Organizing committee "Heavy ion therapy workshop"	Department of Energy (DOE) and NCI, Bethesda, MD
2013	Co-chair, "Expanding Horizons 2013"	Bethesda, MD
2014	Mini-symposium "Optimizing the dynamics of radiation therapy of cancer"	SIAM Opt meeting, San Diego, CA

International

2000	Organization of ICCR 2000 meeting, Heidelberg (with Wolfgang Schlegel)	International Conference on the Use of Computers in Radiation Therapy
2004	Organization of "The Interdisciplinary Experts' Workshop on Intensity-Modulated Radiation Therapy, Medical Imaging, and Optimization Theory" (with Yair Censor and Gabor Herman)	Department of Mathematics, University of Haifa, Israel

2004	Scientific committee, ICCR 2004, Seoul, Korea	International Conference on the Use of Computers in Radiation Therapy
2008	Faculty opponent, PhD thesis defense of Peter Kimstrand	University of Uppsala, Sweden
2009	Theme Chair "Radiation Oncology" (with Uwe Oelfke)	World Congress Medical Physics and Biomedical Engineering, Munich, Germany
2009	Organizing committee, "Mini Conference on Multicriteria Optimization Techniques in Radiation Therapy" (with David Craft)	International conference at Massachusetts General Hospital, Boston
2015	Organizing committee, Radiation Oncology Track	World Congress on Medical Physics and Biomedical Engineering, Toronto, Canada
2015	Thesis committee, PhD thesis defense of Marco Pinto	University of Lyon, France
2018-	Co-chair	RAPTOR: real-time adaptive particle therapy
2018-	Co-founder and co-chair of the international consortium	Optimal Stopping in Radiation Therapy (OSRT)
2019	Scientific committee, ICCR 2019, Montreal, Canada	International Conference on the Use of Computers in Radiation Therapy
2020-	Consultant for Report Committee 32: Dose Prescription, Reporting and Recording in Advanced Optimization Strategies: Application to Dose Painting and Robust Planning	International Commission on Radiation Units and Measurements (ICRU)
2020	Thesis committee, PhD thesis defense of Archonteia Kyroudi	University of Lausanne, Switzerland
2021	Thesis committee, PhD thesis defense of Silvia Fabiano	University of Zürich, Switzerland
2021-	Scientific Advisory Board	Helmholtz-Zentrum Dresden-Rossendorf, Germany

Professional Societies:

1986-	Deutsche Physikalische Gesellschaft (DPG)	
1993-	American Association of Physicists in Medicine (AAPM)	
	2001-2004	Member, IMRT subcommittee, Liaison from European Society for Therapeutic Radiology and Oncology (ESTRO)
	2005-2007	Member, work group on IMRT
	2006-2007	Therapy track organizer
	2007	Chair, Therapy Track (Scientific Program Subcommittee)

	2007-2008	Scientific Program Director, Therapy, AAPM 50th annual meeting
	2007-2013	Member, Joint Working Group for Research Seed Funding Initiative
	2008	Scientific Program Co-Director, Therapy
	2010-2017	Co-Chair with Robert Jeraj, Working Group on Future Research and Academic Medical Physics (FUTURE)(WGFRMP)
	2017	Co-Chair: Provocative Questions in Medical Physics, Boston meeting
	2018-2019	Member, Chiefs of Academic Medical Physics Programs
	2018-2020	Vice-Chair, Working Group on Future Research and Academic Medical Physics (FUTURE)(WGFRMP)
	2019-	Member, Management of Medical Physics Programs and Departments (MMPPD)
1995-	Deutscher Hochschulverband (DHV) (German Society of University Teachers)	
1996-	European Society for Therapeutic Radiology and Oncology (ESTRO)	
	1997, 2001	Member, scientific program committee, annual meeting
	1998-2002, 2004-2006	Teaching staff ESTRO course on conformal radiotherapy, Amsterdam, The Netherlands
	2018-	Member, task group “Future of Medical Physicists in Radiation Oncology”, co-sponsored by AAPM
	2019	Co-organizer, think tank “The most provocative questions for medical physicists in Radiation Oncology”, co-sponsored by AAPM
	2019	Co-organizer, with Jan Unkelbach, 3rd ESTRO physics workshop “Computational methods for clinical target volume definition”, co-sponsored by AAPM
	2021	Co-chair, with Patrick Wohlfahrt and Vicki Taasti, 4th ESTRO physics workshop “Clinical Translation of CT Innovations in Radiation Oncology: Opportunities, Requirements and Standardisation”
2000-	Deutsche Gesellschaft für Medizinische Physik (DGMP)	

2008-2009	American Society for Therapeutic Radiology and Oncology (ASTRO)	
	2008-2009	Member, Radiation Physics Committee of the Research Council
2017-	American Physical Society	
	2017-2020	Secretary and Treasurer, Topical Group on Medical Physics (GMED), co-sponsored by AAPM

Grant Review Activities:

2002-2010	Radiation Therapeutics and Biology Study Section	NCI
	2002-2010	Ad-hoc member
2005-2008	Special emphasis panel	NCI
	2005-2008	Reviewer, Program Project Grants (P01), including presentation to parent committee
2018	Helmholtz Impulse Fund	Helmholtz Association (largest scientific organization in Germany)
	2018	Reviewer, International Helmholtz Research Schools

Editorial Activities:

- **Ad hoc Reviewer**

Physics in Medicine and Biology

Medical Physics

Radiotherapy and Oncology

International Journal of Radiation Oncology, Biology, Physics

Physical Review Journals

IEEE Journals

- **Other Editorial Roles**

1997-2001, 2006-	International Advisory Board	Physics in Medicine and Biology
1997-2005	Editorial Board	Physica Medica
2002-2005	Editorial Board	Physics in Medicine and Biology
2003-	Editorial Board	Radiotherapy and Oncology

2004	Editor	High-Precision Radiation Therapy of Moving Targets. Bortfeld T, Chen GTY eds. Seminars in Radiation Oncology. 2004;14(1):1-100.
2007-2013	Editorial Board	European Journal of Medical Physics
2007	Advisory Board	Medizinische Physik
2013	Editor	Controversies in Proton Therapy. Brada M, Bortfeld T eds. Seminars in Radiation Oncology. 2013;23(2):75-153.
2020-	Editorial Review Board	Physical and Engineering Sciences in Medicine
2021	Guest Editor	IEEE Transactions on Radiation & Plasma Medical Sciences, special issue on advanced topics in particle radiotherapy, Jee K-W, Bortfeld T, El Naqa I, Dong L, guest editors
2021	Editor, with T. Rock Mackie	Medical Physics virtual issue on "Advances in radiation treatment delivery and quality assurance" https://aapm.onlinelibrary.wiley.com/doi/toc/10.1002/(ISSN)2473-4209.advances-in-radiation-treatment-delivery-and-qa

Honors and Prizes:

1990	Richtzenhain Award	German Cancer Research Center (DKFZ)	Best dissertation in cancer research in 1990
1994	Helax-Award	Helax AB, Uppsala, Sweden	Best scientific contribution at XI ICCR (International Conference on the Use of Computers in Radiotherapy)
1995	Young Investigator Award, 3rd place	American Association of Physicists in Medicine (AAPM)	Outstanding scientific paper presentation at 1995 annual AAPM meeting
2001	German Innovation Award (Deutscher Zunkunftspreis) finalist (top 4)	The German President	Development of intensity-modulated radiation therapy (IMRT)
2004	Fellow	Institute of Physics, London	
2008	Artium Magistrum, honoris causa	Harvard University	

2009	Fellow	American Association of Physicists in Medicine (AAPM)	
2015	Alfred-Breit-Preis (highest award of the DEGRO)	German Society for Radiation Oncology (DEGRO)	Intensity-modulated radiation therapy (IMRT)
2016	Wissenschaftspreis: Forschung im Verbund (Science Award: Research Networks)	Fraunhofer Society	Multi-criteria optimization (MCO) in radiation therapy
2018	Glocker medal (highest award of the DGMP)	German Society for Medical Physics (DGMP)	
2019	Australia-Harvard fellowship	Harvard Club of Australia foundation	
2021	Elected member	German National Academy of Sciences Leopoldina	Scientific excellence
2022	Honorary member	European Society for Radiotherapy and Oncology (ESTRO)	Outstanding scientific contributions in the field of Radiation Oncology

Report of Funded and Unfunded Projects

Past

1995-1996	Implementation of a fast photon dose calculation algorithm into the 3D treatment planning program "PLATO" Nucletron B.V., Veenendaal, The Netherlands PI – Investigator initiated
1996-1999	Developments of methods for the generation of intensity modulated beams with the help of a LINAC-integrated multileaf collimator Siemens Medical Systems, Concord, CA Co-PI – Investigator initiated
1997-2000	Optimization of combined therapy with electrons and photons Deutsche Forschungsgemeinschaft (DFG) Co-PI – Investigator initiated
1997-2002	Conformal radiotherapy with inverse planning and intensity modulated photon beams Tumorzentrum Heidelberg/ Mannheim Co-PI – Investigator initiated
2000-2002	Optimization of diagnostics and therapy of breast cancer: Advances in radiotherapy, physical and technical aspects Helmholtz-Gemeinschaft Deutscher Forschungszentren (HGF) Co-PI – Investigator initiated
2000-2002	Optimization and verification of radiotherapy with intensity modulated photon beams British-German Academic Research Collaboration PI – Investigator initiated
2001-2003	Radioplan Bundesministerium für Bildung und Forschung (BMBF) Co-PI

2001-2003 A dynamic real-time tool for improved planning of conformal radiotherapy
Deutsche Krebshilfe
PI – Investigator initiated

2002-2014 Proton Radiation Therapy Research
NIH/NCI P01 CA21239
Project-PI, Project 3 ($2,322,378)
Project-PI, Project 4 ($2,007,712)

2004-2008 Robust IMRT Planning Based on EUD Criteria
US / Israel Binational Science Foundation
PI – Investigator initiated

2004-2012 Multi-Criteria IMRT Optimization
NIH/NCI R01 CA103904
PI ($2,443,980)

2005-2007 Proton Radiotherapy Optimization
Siemens Medical systems
PI – Investigator initiated

2007-2013 Management of Breathing Effects in Radiotherapy Planning
NIH/NCI R01 CA118200
PI ($1,598,444)

2008-2009 Multi-Criteria IMRT Optimization
MGH ECOR formulaic bridge support
PI ($57,500)

2008-2010 Clinical Implementation of Research Results
NIH/NCI C06 CA059267 (Federal Share of program income)
PI – Investigator initiated

2008-2011 Outcome Assessment: MRI Imaging of Radiation Induced Tissue Damage
NIH/NCI C06 CA059267 (Federal Share of program income)
PI ($374,173)

2009-2020 Optimizing the parameters of external beam radiation therapy
Philips Medical Systems
PI ($1,203,383)

2008-2021 Multi-criteria optimization for radiation therapy
Raysearch laboratories, Stockholm, Sweden
PI ($675,000)

Current

2015-2024 Therapy Imaging Program
NIH/NCI C06 CA059267 (Federal Share of program income)
PI ($1,443,728, years 1,2)

2020-2023 International research network “Optimal stopping in radiation therapy”
German Research Foundation DFG TH 1569/3-1
Partner

2021-2024 Innovative Training Networks, Marie Sklodowska-Curie Actions: “RAPTOR Real-time Adaptive Particle Therapy Of cancer”
European Union, EU 955956
Partner

2022-2027 Automated interactive definition of the clinical target volume in radiation oncology
NIH/NCI R01CA266275
PI

2022-2027 An Ionizing Radiation Acoustics Imaging (iRAI) Approach for guided Flash Radiotherapy

NIH/NCI R01CA266803
Co-PI

Projects Submitted for Funding

Training Grants and Mentored Trainee Grants

2009-2019 Training Future Proton Scientists
NIH/NCI C06 CA059267 (Federal Share of program income)
PI ($858,476)

Unfunded Current Projects

2020 Democratization of proton therapy

Report of Local Teaching and Training

Teaching of Students in Courses:

1996	Exercises in Mechanics Physics undergraduate students	University of Heidelberg 2 hours / week, 15 weeks
1996, 1997	Exercises in Electricity and Magnetism Physics undergraduate students	University of Heidelberg 2 hours / week, 15 weeks per year
1996-2000 5 years	Seminar: Physical methods in medicine Physics undergraduate students	University of Heidelberg 2 hours / week, 15 weeks per year
1998	Medical Physics I (course created with Uwe Oelfke) Physics undergraduate students	University of Heidelberg 2 hours / week, 15 weeks
1999	Medical image reconstruction and therapy planning (course created with Uwe Oelfke) Physics undergraduate students	University of Heidelberg 2 hours / week, 15 weeks
2000, 2001	Exercises in Relativity and Quantum Mechanics Physics undergraduate students	University of Heidelberg 2 hours / week, 15 weeks per year
1994, 1997, 2001 3 years	CT imaging and image reconstruction Graduate students in the graduate student program "3-D tumor diagnostics and therapy using radiological methods and lasers"	University of Heidelberg 4 hours per year
2007	HST.187 (course created de novo): Physics of Radiation Oncology – Sharpening the Edge Graduate students	Harvard/MIT Health Sciences and Technology (HST) Program 2 hours per week, 13 weeks
2008	HST.187 (course created de novo): Heavy Charged Particles for Cancer Radiation Therapy Graduate students	Harvard/MIT Health Sciences and Technology (HST) Program 2 hours per week, 13 weeks

2009	HST.531: Medical Physics of Proton Radiation Therapy Graduate students	Harvard/MIT Health Sciences and Technology (HST) Program 2 hours per week, 13 weeks
2013, 2015	HST.S14: Optimization problems in radiation therapy and medical imaging	Harvard/MIT Health Sciences and Technology (HST) Program 2 hours per week, 12 weeks per year

Formal Teaching of Residents, Clinical Fellows and Research Fellows (post-docs):

2002-2004 3 years	Radiation physics Radiation Oncology residents	HMS 2x2 hours per year

Mentored Trainees and Faculty:

1990-1991	Kay-Uwe Kasch, PhD / Professor of Medical Radiation Physics, Dean for Mathematics, Physics, Chemistry at Beuth University of Applied Sciences, Berlin Career stage: MS student, Radiation Protection Physics (Dörschel), Dresden. Mentoring role: thesis co-advisor. Accomplishments: fast dose calculation.
1990-1994	Carsten Schulze, PhD / Team Manager, Siemens Career stage: PhD student, Physics, Heidelberg. Mentoring role: thesis advisor. Accomplishments: fast 3D kernel-based dose calculation.
1992-1996	Jörg Stein, PhD / Consultant Career stage: MS student, PhD student, Physics, Dresden, Heidelberg. Mentoring role: thesis advisor. Accomplishments: intensity modulation with multileaf collimators, beam angle optimization, impactful publications.
1994-1997	Konrad Preiser, PhD / Professor, BA Mannheim Germany Career stage: Dr.sc.hum. student, Medical Informatics, Heidelberg. Mentoring role: thesis advisor. Accomplishments: interactive user interface for inverse planning, methods have been copied and adopted by all treatment planning systems around the globe and are still in use today.
1995-1996	Klaus Hartwig, MS / Software developer Career stage: MS student, Physics, Heidelberg. Mentoring role: thesis advisor. Accomplishments: beam intensity modulation with compensators for clinical practice.
1995-1996	Andreas Mahr, PhD / Vice Rector and Dean of the Faculty for Technology, cooperative State University Heidenheim Career stage: MS student, Medical Informatics, Heilbronn. Mentoring role: thesis advisor. Accomplishments: relational database for physical base data in treatment planning.
1997-1998	Andreas Helbig, MS Career stage: MS student, Physics, Heidelberg. Mentoring role: thesis advisor. Accomplishments: dosimetric verification of IMRT.
1997-2000	Gunilla Küster, PhD / European Patent Office, Munich Germany Career stage: PhD student, Physics, Heidelberg. Mentoring role: thesis advisor. Accomplishments: Monte Carlo based hardware optimization for IMRT.

1997-2000 Lothar Spies, PhD / Managing director and founder, Jung diagnostics
Career stage: PhD student, Physics, Heidelberg. Mentoring role: thesis advisor. Accomplishments: cone-beam CT, scatter correction.

1997-2001 Burkhard Groh, PhD / Siemens
Career stage: PhD student, Physics, Heidelberg. Mentoring role: thesis advisor. Accomplishments: flat panel imager for image guidance.

1997-2001 Uwe Oelfke, PhD / Professor and Head of Joint Department of Physics, Institute of Cancer Research, London
Career stage: Visiting scientist, DKFZ and University of Heidelberg. Mentoring role: getting started in Heidelberg after return to Germany from Canada. Accomplishments: started Medical Physics teaching program in the Physics Department. Collaboration on inverse planning, several joint publications.

1997-2001 Alexander Werling, PhD
Career stage: PhD student, Physics, Heidelberg. Mentoring role: thesis advisor. Accomplishments: scatter correction in PET imaging.

1998-1999 Julia (Ahlswede) Albright / VP solutions, NextGen Healthcare
Career stage: MS student, Physics, Heidelberg. Mentoring role: thesis advisor. Accomplishments: assessment of treatment techniques and collimation.

1998-2001 Matthias Ebert, PhD / Teacher
Career stage: PhD student, Informatics, Heidelberg-Mannheim. Mentoring role: thesis advisor. Accomplishments: image reconstruction and image guidance for conformal radiation therapy.

1999-2001 Stefan Wesarg, PhD / Head of competence center at Fraunhofer IGD
Career stage: MS student, Physics, Heidelberg. Mentoring role: thesis advisor. Accomplishments: short scan algorithms for limited angle CT.

1999-2002 Simeon Nill, PhD / Clinical scientist, Institute of Cancer Research, London
Career stage: PhD student, Physics, Heidelberg. Mentoring role: thesis advisor. Accomplishments: multi-modal treatment planning including intensity-modulated proton therapy.

1999-2002 Luciana Pavel, PhD / Strategic coach
Career stage: PhD student, Physics, Heidelberg. Mentoring role: thesis advisor. Accomplishments: effect of motion on hollow organs such as rectum.

2000-2001 Christian Scholz, PhD / Product Manager, Siemens
Career stage: MS student, Physics, Heidelberg. Mentoring role: thesis advisor. Accomplishments: KonRad treatment planning.

2001-2002 Kimmo Jokivarsi, PhD
Career stage: research fellow. Mentoring role: research supervisor. Accomplishments: quantify effects of organ motion on IMRT delivery. Joint publication has become the most frequently cited paper published in Phys Med Biol in 2002.

2001-2002 Ward Jenneknes, PhD / Department Head Medical Physics and Technology, Maasstad Hospital Rotterdam
Career stage: research fellow. Mentoring role: research supervisor. Accomplishments: development toward IMPT dose delivery.

2001-2003 Christian Thieke, MD PhD / Associate Professor, scientific coordinator LMU Munich
Career stage: PhD student, Physics, Heidelberg. Mentoring role: thesis advisor.

	Accomplishments: multi-criteria treatment planning – development and clinical application, several publications. Varian Physics Award, ESTRO 2003; Richtzenhain award, DKFZ, 2005.
2002-2004	John Wolfgang, PhD / Instructor at HMS, MGH Career stage: postdoctoral fellow, now a clinical physicist and data expert. Mentoring role: research supervisor. Accomplishments: joint publications.
2002-2006	Alexander Scherrer, PhD / Team leader Optimization at Fraunhofer ITWM Career stage: PhD student, Mathematics, Kaiserslautern. Mentoring role: thesis advisor. Accomplishments: multi-criteria optimization in treatment planning – voxel/bixel clustering to accelerate Pareto surface calculation, publications.
2002-	Alexei Trofimov, PhD / Assistant Professor at HMS, MGH Career stage: postdoctoral fellow. Mentoring role: research supervisor. Accomplishments: many impactful publications on inverse planning and intensity-modulated proton therapy. Alexei was the very first recipient of the AAPM Jack Fowler Junior Investigator Award in 2004.
2003	Jan Wilkens, PhD / Professor at TU Munich, Head of Medical Physics at Klinikum rechts der Isar Career stage: PhD student. Mentoring role: research supervisor. Accomplishments: assessment of activation of gold seeds by proton irradiation, technical report.
2003	Nadine Siemer Career stage: MS student. Mentoring role: research supervisor. Accomplishments: inclusion of equivalent uniform dose (EUD) constraints in IMRT optimization.
2003-2008	Benjamin Martin, PhD / Development Manager, MathWorks Career stage: PhD student, Electrical Engineering, Boston University. Mentoring role: thesis advisor. Accomplishments: voxel sampling to accelerate dose optimization, several joint publications.
2004	Michael Fernald Career stage: recipient of AAPM Summer Undergraduate Fellowship. Mentoring role: mentor and host. Accomplishments: motion compensation in IMRT, phantom tests and simulation. Poster presentation at 2005 AAPM annual meeting.
2004	Sven Süptitz Career stage: student, Computer Science, BA Mannheim. Mentoring role: research supervisor. Accomplishments: publication database development and deployment.
2004-2006	Katia Parodi / Professor and Chair of Medical Physics, LMU Munich Career stage: postdoctoral fellow. Mentoring role: research advisor. Accomplishments: proton range verification with PET imaging, theory and clinical application at MGH. Several joint publications. Many subsequent awards, including the IEEE Bruce Hasegawa Young Investigator Medical Imaging Science Award (2009) and the AAPM John Laughlin Young Scientist Award (2015).
2004-2007	Timothy Chan, PhD / Professor of Industrial Engineering, University of Toronto Career stage: PhD student, Operations Research, MIT. Mentoring role: thesis advisor. Accomplishments: robust planning for treatment of lung tumors, several joint publications. Dantzig Dissertation Award from INFORMS (2007).
2004-2009	Antje Knopf, PhD / Associate Professor, Scientific Coordinator, National Center for Tumor Diseases, Germany Career stage: MS student, then PhD student, Physics, Heidelberg. Mentoring role: thesis

advisor. Accomplishments: proton range verification through PET. Several publications. AAPM Young Investigator Award 2nd place (2007). ESTRO-Varian award (2008).

2004- David Craft, PhD / Assistant professor at HMS, MGH
Career stage: postdoctoral fellow, now faculty. Mentoring role: research advisor. Accomplishments: Multi-Criteria Optimization (MCO), from early development to clinical application and routine treatment planning. Many joint publications.

2005-2007 Tarek Halabi, PhD / Entrepreneur
Career stage: PhD student, Physics, UMass Amherst. Mentoring role: thesis advisor. Accomplishments: multi-criteria optimization with dose-volume criteria, several joint publications.

2005-2008 Sairos Safai, PhD / Physicist, Paul Scherrer Institute (PSI), Switzerland
Career stage: postdoctoral fellow. Mentoring role: research supervisor. Accomplishments: deeper understanding of the advantages of intensity modulation in proton therapy, detailed comparison of the penumbra in collimated broad beams and pencil beam scanning, joint publications.

2005-2016 Jan Unkelbach, PhD / Assistant Professor of Medical Physics, University of Zürich, Switzerland
Career stage: PhD student, then postdoctoral fellow, then Assistant Professor. Mentoring role: thesis advisor and research supervisor. Accomplishments: robust optimization in proton therapy planning, optimization of arc therapy planning, modeling tumor spread for glioma, many joint publications.

2007-2009 Omid Nohadani, PhD / Associate Professor of Industrial Engineering and Management Sciences, Northwestern University
Career stage: postdoctoral fellow. Mentoring role: research supervisor. Accomplishments: motion compensation with 4D optimization, stochastic optimization for improved dosimetric robustness, joint publications in those areas.

2008-2009 Michael Gensheimer, MD / Clinical Associate Professor, Radiation Oncology, Stanford
Career stage: MD student. Mentoring role: research supervisor, research year. Accomplishments: proton range verification through MRI changes in the spine for medulloblastoma patients, highly original publication.

2008, 2009 Steffen Remmele, PhD / CTO, PowerBrain.Shop
Career stage: PhD student, Applied Informatics, Heidelberg. Mentoring role: thesis advisor. Accomplishments: PET imaging for proton range verification, deconvolution of the dose from the PET image, joint publication.

2009-2011 Dualta McQuaid, PhD / Medical Physicist, Royal Marsden Hospital, Sutton, UK
Career stage: postdoctoral fellow. Mentoring role: research supervisor. Accomplishments: 4D treatment planning, multicriteria VMAT optimization, publications.

2009-2013 Jagdish Ramakrishnan, PhD / Research scientist at Facebook
Career stage: PhD student, Electrical Engineering, MIT. Mentoring role: thesis advisor. Accomplishments: dynamic programming to optimize the time course of radiation therapy, several publications.

2010-2011 Yading Yuan, PhD / Associate Professor of Radiation Oncology, Mt Sinai Hospital, NY
Career Stage: Physics resident. Mentoring role: research supervisor. Accomplishments: quantification of MRI changes in liver after proton therapy, joint publications.

2010-2012	Wei Chen, PhD / Software engineer at Facebook Career stage: postdoctoral fellow. Mentoring role: research supervisor. Accomplishments: robust multicriteria treatment planning, highly original and impactful publications.
2011	Jeremiah Wala, MD / Internal Medicine Resident, UCSF Career stage: student, HST program at Harvard-MIT. Mentoring role: research supervisor. Accomplishments: VMAT optimization, joint publications.
2011-2013	Ehsan Salari, PhD / Associate Professor of Industrial and Manufacturing Engineering, Wichita State University Career stage: postdoctoral fellow. Mentoring role: research supervisor. Accomplishments: combined optimization of radiation and chemotherapy, VMAT optimization, several joint publications.
2011-	Joost Verburg, PhD / Assistant Professor at HMS, MGH Career stage: PhD student, Physics, University of Eindhoven. Mentoring role: thesis advisor. Accomplishments: prompt gamma imaging development for proton range verification/correction. Joint publications. Several awards including AAPM Young Investigator Award 3rd place (2015), Michael Goitein award at PTCOG (2019).
2012	Russell Wolf Career stage: student, Physics, Cornell University. Mentoring role: research supervisor. Accomplishments: effect of MR magnet on proton beam, publication.
2012	Nathalie Rochet, MD Career stage: visiting fellow with travel award from Heidelberg. Mentoring role: research supervisor. Accomplishments: use of multicriteria optimization in whole abdomen radiation therapy, conference presentation.
2012	Christian Richter / Professor and Chief of Physics, OncoRay Dresden Career stage: PhD student, University of Dresden. Mentoring role: research supervisor. Accomplishments: dynamics of MRI changes after proton therapy in liver, potential for proton range verification, patient response assessment, joint publications.
2014	Birgit Müller, PhD Career stage: intern from TU Munich. Mentoring role: research supervisor. Accomplishments: study on physician-driven multicriteria optimization, publication.
2014-2015	Roland Schnürer, PhD / Application Engineer, Accelerator Science and Technology Centre UK Career stage: MS student. Medical Physics, Düsseldorf. Mentoring role: thesis advisor. Accomplishments: in-vivo beam range verification for pencil beam scanning. Thesis completed, conference presentation.
2014-	Susu Yan, PhD / Instructor at HMS, MGH Career stage: Physics resident, research year, then faculty member. Mentoring role: research supervisor. Accomplishments: democratization of proton therapy, work with MIT robotics, several publications and patents.
2015-	Marco Langhans, MS Career stage: MS student, University of Oldenburg, then PhD student, University of Freiburg. Mentoring role: thesis advisor. Accomplishments: heuristic for 4π treatment delivery, CTV auto segmentation, several publications.
2017-2019	Fernando Hueso-González, PhD Career stage: postdoctoral fellow. Mentoring role: research supervisor. Accomplishments:

clinical deployment of prompt gamma range detection, collision detection during treatment planning, publications.

2018- Ali Ajdari, PhD / Instructor at HMS, MGH
Career stage: postdoctoral fellow, then faculty. Mentoring role: research advisor. Accomplishments: development of the OSRT concept, Optimal Stopping in Radiation Therapy, creation of international OSRT consortium, joint publications.

2018-2023 Sebastian Tattenberg, MS
Career stage: PhD student, Physics, LMU Munich. Mentoring role: thesis co-advisor. Accomplishments: quantification of the benefit of range uncertainty reduction, publication.

2019-2020 Patrick Wohlfahrt / Siemens Healthineers
Career stage: postdoctoral fellow. Mentoring role: research supervisor. Accomplishments: clinical application of dual energy CT, invited review paper, 2021 ESTRO Physics Workshop organization.

2019-2021 Stefan ten Eikelder, MS
Career stage: PhD student, Operations Research, Tilburg University. Mentoring role: thesis advisor. Accomplishments: treatment length optimization, adjustable robust optimization for treatment planning, conic optimization algorithms, several publications.

2020- Samantha Hickey, MS
Career stage: PhD student, Medical Physics, University of Freiburg. Mentoring role: thesis co-advisor.

2021- Zihang Qiu, MS
Career stage: PhD student, Operations Research, University of Amsterdam. Mentoring role: thesis co-advisor.

2022- Beatrice Foglia, MS
Career stage: PhD student, Physics, LMU Munich. Mentoring role: thesis co-advisor.

Local Invited Presentations:

☒ *No presentations below were sponsored by 3rd parties/outside entities*

☐ *Those presentations below sponsored by outside entities are so noted and the sponsor(s) is (are) identified.*

2012 Harvard Applied Physics Colloquium: Physics Against Cancer

Report of Regional, National and International Invited Teaching and Presentations

☒ *No presentations below were sponsored by 3rd parties/outside entities*

☐ *Those presentations below sponsored by outside entities are so noted and the sponsor(s) is (are) identified.*

Before 2001:

- Over 20 invited teaching lectures at international workshops, summer schools, and conferences (e.g., ESTRO, SGSMP, ESMP, DGMP winter school, AIFB, CCIO (Warsaw), Oncological Center Moscow, CAMS (Beijing))

- Over 30 invited lectures and plenary presentations at scientific conferences and seminars (e.g., Nobel conference 2000, DEGRO 1999+2000, ASTRO 1999, AAPM 1999, ICCR 1997, DGMP, ESTRO 1995+96+97+98+99+2000, ART (Munich) 1991, Karolinska Institute (Stockholm, Sweden), PSI (Villigen, Switzerland), MD Anderson Cancer Center (Houston, TX), Memorial Sloan Kettering Cancer Center (New York), MGH)

- Faculty opponent, thesis defense of Anders Gustafsson (Karolinska Institute + University of Stockholm) 1996

2001 and beyond:

Regional

2002-2004 3 years	Undergraduate teaching at Northeastern University: Seminar Course in Radiation Oncology Physics (jointly with George TY Chen), 2 hours / week, 10 weeks per year Boston, MA
2004	NSF Information and Data Management Workshop Cambridge, MA
2005	American Association of Physicists in Medicine (AAPM), New England Chapter meeting Andover, MA
2007	PUMBA: first ORC healthcare conference (MIT) Cambridge, MA
2009	American Association of Physicists in Medicine (AAPM), New England Chapter meeting Boylston, MA
2013	American Association of Physicists in Medicine (AAPM), New England Chapter meeting, Keynote Boston, MA
2019	New England Chapter of the AAPM Boston, MA

National

2001	International Symposium on 3D Conformal Radiation Therapy and Intensity Modulated Radiation Therapy Williamsburg, VA
2002	ORART – Operations Research Applied to Radiation Therapy Washington, DC
2002	Visiting Professor, University of Wisconsin-Madison, Department of Medical Physics Madison, WI

2003	7th International Symposium on 3D Conformal Radiation Therapy and Intensity Modulated Radiation Therapy San Francisco, CA
2003	Visiting Professor, Stony Brook University Hospital, Division of Radiation Physics Stony Brook, NY
2003	IMRT Practicum at Sea Fort Lauderdale, FL
2003	American Association of Physicists in Medicine (AAPM), Summer School Colorado Springs, CO
2004	American Society for Therapeutic Radiology and Oncology (ASTRO), Annual meeting Atlanta, GA
2004	Visiting Professor, Memorial Sloan Kettering Cancer Center, Department of Medical Physics New York, NY
2004	Visiting Professor, University of Michigan at Ann Arbor, Department of Radiation Oncology Ann Arbor, MI
2004	Visiting Professor, MD Anderson Cancer Center, Department of Radiation Physics Houston, TX
2004	American Association of Physicists in Medicine (AAPM), Annual meeting Pittsburgh, PA
2005	Image-Guided IMRT Practicum at Sea Seattle, WA
2005	American Association of Physicists in Medicine (AAPM), Annual meeting Seattle, WA
2005	Visiting Professor, Massachusetts Institute of Technology, Operations Research Center Cambridge, MA
2005	Visiting Professor, Fox Chase Cancer Center, Department of Radiation Physics Philadelphia, PA
2005	Radiological Society of North America (RSNA), Annual meeting Chicago, IL
2006	American Association of Physicists in Medicine (AAPM), Annual meeting Orlando, FL
2006	Visiting Professor, Rensselaer Polytechnic Institute, Department of Electrical Engineering Troy, NY
2007	American Association of Medical Dosimetrists (AAMD), Annual meeting New Orleans, LA
2007	American Association of Physicists in Medicine (AAPM), Annual meeting Minneapolis, MN
2007	MD Anderson Roundtop meeting Roundtop, TX

2008	ASTRO IGRT symposium Newport Beach, CA
2008	NIRS-MD Anderson symposium on clinical issues for particle therapy Houston, TX
2008	AAPM annual meeting Houston, TX
2008	ASTRO annual conference Boston, MA
2009	12th Annual Nagalingam Suntharalingam Lecture, and Visiting Professor Thomas Jefferson Hospital and University Philadelphia, PA
2009	AAPM conference on promises and perils of proton therapy Baltimore, MD
2009	AAPM annual meeting Anaheim, CA
2010	AAPM annual meeting Philadelphia, PA
2010	ASTRO annual conference San Diego, CA
2010	City University New York, invited lecture New York, NY
2011	Visiting Professor, University of Pennsylvania Medical School, Department of Radiation Oncology Philadelphia, PA
2011	Visiting Professor, Memorial Sloan Kettering Cancer Center, Departments of Radiation Oncology and Medical Physics New York, NY
2012	ASTRO annual meeting Boston, MA
2013	AAPM annual conference Indianapolis, IN
2014	AAPM annual conference (3 invited talks) Austin, TX
2014	Symposium in honor of Rock Mackie Madison, WI
2015	Rutgers University New Brunswick, NJ
2015	Visiting Professor, University of Chicago Medical School, Department of Radiation Oncology Chicago, IL
2015	AAPM Summer School Colorado Springs, CO

2015	AAPM annual conference Anaheim, CA
2015	RSNA Chicago, IL
2016	Samulski Lecture, Duke University, and Visiting Professor Department of Radiation Oncology Durham, NC
2017	AAPM annual conference Denver, CO
2018	Winter Institute of Medical Physics (keynote lecture) Breckenridge, CO
2018	ASTRO annual conference San Antonio, TX
2019	Barry Berman Memorial Lecture, George Washington University, Department of Physics Washington, DC
2022	Increase the global access to proton radiation therapy Global Health Catalyst Summit Washington, DC

International

2001	ISRO-ICRO, 6th International Congress of Radiation Oncology Melbourne, Australia
2001	IMRT and Other Conformal Techniques in Practice, course of the European Society of Therapeutic Radiology and Oncology (ESTRO) Amsterdam, The Netherlands
2001	3rd Takahashi Memorial International Workshop on 3 Dimensional Conformal Radiotherapy Nagoya, Japan
2002	International Meeting on Progress in Radio-oncology ICRO/ÖGRO Salzburg, Austria
2002	IMRT and Other Conformal Techniques in Practice, course of the European Society of Therapeutic Radiology and Oncology (ESTRO) Amsterdam, The Netherlands
2002	European Society for Therapeutic Radiology and Oncology (ESTRO), Annual meeting Prague, Czech Republic
2003	European Society for Therapeutic Radiology and Oncology (ESTRO) Dresden, Germany
2003	German Society of Medical Physics (DGMP), Annual meeting Heidelberg, Germany
2004	The Interdisciplinary Experts' Workshop on Intensity-Modulated Radiation Therapy Haifa, Israel

2004	IMRT and Other Conformal Techniques in Practice, course of the European Society of Therapeutic Radiology and Oncology (ESTRO) Amsterdam, The Netherlands
2004	Visiting Professor, Royal Marsden Hospital, Department of Physics Sutton, UK
2004	European Society for Therapeutic Radiology and Oncology (ESTRO), Annual meeting Amsterdam, The Netherlands
2005	IMRT and Other Conformal Techniques in Practice, course of the European Society of Therapeutic Radiology and Oncology (ESTRO) Amsterdam, The Netherlands
2005	Visiting Professor, Fraunhofer Institute of Mathematics, Department of Optimization Kaiserslautern, Germany
2005	Symposium 60th Birthday of Wolfgang Schlegel Heidelberg, Germany
2006	International Conference on Translational Research Lugano, Switzerland
2006	PTCOG satellite workshop on Intensity-Modulated Proton Therapy Zürich, Switzerland
2006	IMRT and Other Conformal Techniques in Practice, course of the European Society of Therapeutic Radiology and Oncology (ESTRO) Copenhagen, Denmark
2006	European Society for Therapeutic Radiology and Oncology (ESTRO), Annual meeting Leipzig, Germany
2006	IMRT and Other Conformal Techniques in Practice, course of the European Society of Therapeutic Radiology and Oncology (ESTRO) Gliwice, Poland
2007	Monte Carlo: 3rd McGill international workshop Montreal, Canada
2007	European Society for Therapeutic Radiology and Oncology (ESTRO), Bi-annual physics meeting Barcelona, Spain
2007	European Cancer Conference (ECCO) Barcelona, Spain
2008	ESTRO workshop on Physics in Radiation Oncology – future perspectives Nyon, Switzerland
2008	Haddow Fellowship (3 week visit), Royal Marsden Hospital, Institute of Cancer Research, Department of Physics Sutton, UK
2008	Symposium 60th Birthday of Steve Webb Sutton, UK
2009	SGSMP, Swiss Society of Medical Physics Basel, Switzerland

2009	World Congress Medical Physics and Biomedical Engineering Munich, Germany
2010	DGMP, German Society of Medical Physics Freiburg, Germany
2010-2015 6 years	Graduate teaching at Heidelberg University in Germany: Master Online – Optimization and inverse planning, 2x2 hours per year Online course
2011	ESTRO bi-annual physics conference London, UK
2011	SIAM conference on optimization Darmstadt, Germany
2011	New developments in the planning and delivery of radiation therapy in the new millennium; 5 day teaching workshop, 22 lectures, shared with Dr. Hsiao-Ming Lu Hong Kong, China
2011	AAPM annual meting Vancouver, Canada
2012	ICTR conference Geneva, Switzerland
2012	ESTRO conference Barcelona, Spain
2013	3rd International Conference on Real-time Tumor-Tracking Radiation Therapy with 4D Molecular Imaging Technique (keynote lecture) Sapporo, Japan
2013	ESTRO conference Geneva, Switzerland
2013	Symposium for Anders Brahme: The roadmap to advanced radiation therapy Stockholm, Sweden
2013	Symposium in honor of Michael Molls, MD Munich, Germany
2013	PTCOG conference (Keynote lecture) Essen, Germany
2014	ESTRO annual conference Vienna, Austria
2014	Workshop on Range Assessment and Dose Verification in Particle Therapy Dresden, Germany
2014	Proton Therapy Symposium Uppsala, Sweden
2015	Science Day, Dalhousie University Halifax, Canada
2015	ESTRO annual conference Barcelona, Spain

2015	Turkish Society of Medical Physics, annual conference Trabzon, Turkey
2015	DEGRO annual conference (keynote lecture) Hamburg, Germany
2015	Doppler workshop, MRI Vienna, Austria
2015	Langendorff Symposium Freiburg, Germany
2016	ICTR-PHE Geneva, Switzerland
2016	ICCR London, England
2016	Expert workshop: Radiobiology of proton therapy Dresden, Germany
2017	ESTRO annual conference Vienna, Austria
2018	AAPM ISEP Ljubljana, Slovenia
2018	CARO-COMP-CMRT (keynote lecture) Montreal, Canada
2019	Langendorff Symposium Freiburg, Germany
2019	Farewell symposium Wolfgang Schlegel Heidelberg, Germany
2019	3rd ESTRO physics workshop Budapest, Hungary
2019	Engineering and Physical Sciences in Medicine Conference (keynote) Perth, Australia
2019	Public Lecture, University of Western Australia Perth, Australia
2019	SGSMP, Swiss Society of Radiobiology and Medical Physics (keynote) Zürich, Switzerland
2020	Clinical target volume definition - from Art to Science Centre Léon Bérard Lyon, France
2020	Definition des klinischen Zielvolumens – Kunst und Wissenschaft Department of Radiation Oncology Freiburg, Germany
2020	Analytics in the fight against cancer Analytics for a better world webinar virtual

2020	Curing Cancer as a Medical Physicist MSc program in Medical Physics at the Polytechnic University Hong Kong (virtual)
2020	Quo Vadis, Medizinische Physik? Perspektive 2030 German Society for Medical Physics Leipzig, Germany (virtual)
2020	Advancing Cancer Medicine in Hospitals and Research Centers - a Personal Perspective Ljubljana, Slovenia (virtual)
2020	Target delineation decisions in interactive treatment planning ESTRO annual meeting Vienna, Austria (virtual)
2020	Transforming CTV definition from art to science ESTRO annual meeting Vienna, Austria (virtual)
2020	The target of radiation therapy MICCAI conference Lima, Peru (virtual)
2021	Proton therapy in standard treatment rooms (Keynote) Annual meeting of the Chinese Society for Medical Physics Wuhan, China (virtual)
2021	Democratizing proton therapy Raptor school Ljubljana, Slovenia (virtual)
2021	Wishlist for future CT development ESTRO physics workshop (virtual)
2021	Treatment plan optimization Munich graduate program in Medical Physics (virtual)
2022	From IMRT to innovative proton therapy Centenary of Radiation Oncology in Dresden (virtual)
2022	In 10 years particle therapy will be in a better place than now Debate at ESTRO annual conference Copenhagen, Denmark
2022	Physik und Mathematik im Kampf gegen den Krebs – Photonen, Protonen, Schwerionen (Physics and Math in the Fight Against Cancer) Leopoldina, German National Academy of Sciences Halle, Germany
2022	Democratizing proton therapy Louvain-la-Neuve, Radiation Oncology Louvain-la-Neuve University campus, Belgium

Report of Clinical Activities and Innovations

Current Licensure and Certification:

1998	Fachkunde im Strahlenschutz (certification in radiation protection for the use of accelerators in medicine, as required by the German legislation)
1998	Certified Medical Physicist (German Society of Medical Physics, DGMP)

Clinical Innovations:

Inverse treatment planning optimization	As part of my PhD dissertation project in 1988-1990, I developed a fast inverse planning algorithm for intensity-modulated radiation therapy (IMRT). Initially a 2D algorithm, it was generalized to 3D and a more accurate dose calculation algorithm was integrated while I was a postdoctoral fellow in Heidelberg in 1991-1992. A modified version of this Opt3D algorithm was clinically deployed for the first IMRT treatment with multileaf collimators at the Sloan Kettering Cancer Center (MSKCC) in 1995.
IMRT with multileaf collimators (MLC)	In 1992-1993, as a postdoctoral fellow at the MD Anderson Cancer Center (MDACC), I developed a method and algorithm for the generation of intensity-modulated fields using a general purpose MLC. We first deployed this method for phantom treatments at MDACC. Later it was also used for the first patient treatment at MSKCC, and became the standard of IMRT delivery worldwide.
Interactive inverse planning	Together with my former student Konrad Preiser, we developed a graphical user interface for Opt3D and focused on its capability to shape 3D dose distributions interactively. The resulting system was called KonRad. It was first deployed for a clinical treatment in Heidelberg in 1997 and was integrated into several commercial treatment planning systems.
Dose volume histogram constraint points in treatment planning	I developed methods to integrate dose-volume constraints in the optimized planning process. With Konrad Preiser we included these constraints as user adjustable parameters in the interactive KonRad user interface. This concept has subsequently been adopted by all treatment planning systems. In combination with the developments above, it formed the basis of modern IMRT, which has since become the state-of-the-art of radiation treatment delivery with over 30 million patients treated as of 2021.
Multi-criteria optimization (MCO)	While KonRad treatment planning is by design fully interactive, it requires trial-and-error to find the input parameter settings that yield the desired treatment plan. With colleagues from Fraunhofer ITWM, we developed MCO methods for treatment planning that let the planner find the most suitable clinical treatment plan directly, by controlling the output rather than the input parameters. We integrated MCO in a commercial planning system in collaboration with RaySearch and deployed it in our clinic at MGH. The MCO approach and the related Pareto concept have been adopted widely in our field.

Report of Technological and Other Scientific Innovations

Optimized treatment planning	Mathematical formulation of the inverse treatment planning problem as a constrained optimization problem (today known as the fluence map optimization problem). Solution via quasi-Newton methods with diagonal approximation of the Hessian matrix. Constraint handling via penalty functions (Bortfeld et al., Phys Med Biol 1990;35:1423-1434). The choice of these methods was based on the insight that the objective function and constraints are convex, and it is therefore unnecessary to resort to stochastic methods such as simulated annealing.
Delivery of intensity-modulated radiation therapy (IMRT) with multileaf collimators (MLC)	Analytical calculation of the MLC "sweep" motion trajectory that creates a desired intensity map, both in the dynamic mode (Stein et al., Radiother Oncol 1994;32:163-173) and the step and shoot mode (Bortfeld et al., Int J Radiat Oncol Biol Phys 1994;28:723-730). Together with the optimized inverse planning method above, this combined approach has been adopted in many other systems and formed the basis of modern IMRT delivery.
Fast dose calculation	Fast 3D kernel-based dose calculation by kernel decomposition into lateral and depth components (Bortfeld et al., Med Phys 1993;20:311-318), inspired by the singular-value decomposition of a matrix. This method has facilitated *interactive* inverse planning with iterative dose calculations on computer hardware of the time. The method is still in use today in commercial treatment planning systems.
Dose-volume histogram (DVH) constraints in inverse planning	Handling of non-convex DVH constraints by fast projection methods (Bortfeld et al., ICCR 1997:1-4). Interactive adjustment of the DVH constraints in the user interface (Preiser et al., ICCR 1997:425-428). This method has subsequently been adopted and implemented in all treatment planning systems; it is still in use today.
Multi-criteria optimization (MCO)	Introduction of the concept of Pareto efficiency in IMRT treatment planning, together with Karl-Heinz Küfer and colleagues from Fraunhofer ITWM, and David Craft at MGH. Development of tools to interactively "navigate" the Pareto frontier, to find the most suitable tradeoff between target coverage and sparing of normal tissues. Concept broadly adopted and implemented in several planning systems today.
Fast multi-dimensional Hartley transform	Convolutions of real-valued functions are efficiently done in the frequency domain using Hartley transforms, without having to deal with the imaginary part of the Fourier transform. I developed an algorithm to calculate the multi-dimensional Hartley transform using one-dimensional fast Fourier transforms (Bortfeld and Dinter, IEEE Trans Signal Process 1995;43:1306-1310).
Analytical model of the Bragg peak	Approximation of the proton Bragg peak by parabolic cylinder functions (Bortfeld, Med Phys 1997;24:2024-2033). This "Bortfeld model" has been used widely from rapid prototyping to clinical treatment planning.
Robust optimization	Development of robust optimization techniques to deal with uncertainties in planning and delivery of both photon (Chan TCY et al., Phys Med Biol 2006;51:2567-2583) and especially proton therapy (Unkelbach et al., Phys Med Biol 2007;52(10):2755-2773). Robust optimization is a better alternative to the use of planning margins and is becoming available in several commercial planning systems.
Reduction of proton range uncertainties	I put the proton range uncertainty problem on the map in our field. I worked with Katia Parodi on PET-based range verification (Parodi et al., Int J Radiat

	Oncol Biol Phys 2007;68(3):920-934). One of the most promising approaches to reduce range uncertainties uses prompt gamma spectroscopy, developed by my former PhD student and now faculty member Joost Verburg (Verburg et al., Phys Med Biol 2013;58(20):L37-49).
Definition of the clinical target volume (CTV)	CTV definition is one of the weakest links in the radiotherapy chain. I am working on strengthening the link through user-guided automated CTV definition, with first demonstrated results in glioma (Shusharina et al., Radiother Oncol 2020;146:37-43).
Democratization of proton therapy	Proton therapy has been denounced as a breathtakingly expensive luxury treatment. My team and I are working toward democratizing proton therapy by making it affordable and available for every patient who is expected to benefit from it. We have recently been the first in the world to retrofit proton therapy in two neighboring treatment rooms that were designed for conventional radiation therapy (Bortfeld and Loeffler, Nature 2017;549:451-453.). A separate building was not needed, which substantially lowered the cost. The next step will be to shrink the size of proton machines further so that they can replace conventional linear accelerators in single conventional treatment rooms. This development will be facilitated by moving the patient around a fixed beam using soft robotics (Buchner, Yan, et al., BioRob 2020;981-988).

Patents granted:

Treatment plan optimization based on equivalent uniform dose (EUD) criteria	Bortfeld T, Thieke C, Niemierko A. Arrangements and methods for treating a subject. U.S. patent 6728336, 2004
Efficient sampling of the Pareto frontier for multicriteria optimization	Craft D, Bortfeld T. System and method for radiation dose control. U.S. patent 8489366, 2013.
Optimization of non-coplanar 4π treatment delivery	Papp D, Unkelbach J, Bortfeld T, Bal M. Volumetric Modulated Arc Therapy (VMAT) with Non-Coplanar Trajectories. U.S. patent 10549115, 2020.
Proton therapy in standard treatment rooms	Bortfeld T, Flanz J, Lu H-M, Yan S. System and method for gantry-less particle therapy. U.S. patent 10880983, 2020.

Report of Education of Patients and Service to the Community

☒ *No presentations below were sponsored by 3rd parties/outside entities*

☐ *Those presentations below sponsored by outside entities are so noted and the sponsor(s) is (are) identified.*

Activities

2019	"Physics in the fight against cancer", Public Lecture, University of Western Australia Perth, Australia

Report of Scholarship

ORCID iD: 0000-0002-3883-0398

Peer-Reviewed Scholarship in print or other media:

Research Investigations

1. **Bortfeld T**, Bürkelbach J, Boesecke R, Schlegel W. Methods of image reconstruction from projections applied to conformation radiotherapy. Phys Med Biol. 1990;35:1423-34.
2. Schlegel W, Pastyr O, **Bortfeld T**, Becker G, Schad L, Gademann G, Lorenz WJ. Computer systems and mechanical tools for stereotactically guided conformation therapy with linear accelerators. Int J Radiat Oncol Biol Phys. 1992;24:781-7.
3. **Bortfeld T**, Schlegel W, Rhein B. Decomposition of pencil beam kernels for fast dose calculations in three-dimensional treatment planning. Med Phys. 1993;20:311-8.
4. **Bortfeld T**, Schlegel W. Optimization of beam orientations in radiation therapy: some theoretical considerations. Phys Med Biol. 1993;38:291-304.
5. Gademann G, Schlegel W, Debus J, Schad L, **Bortfeld T**, Höver KH, Lorenz WJ, Wannenmacher M. Fractionated stereotactically guided radiotherapy of head and neck tumors: a report on clinical use of a new system in 195 cases. Radiother Oncol. 1993;29:205-13.
6. Schlegel W, Pastyr O, **Bortfeld T**, Gademann G, Menke M, Maier Borst W. Stereotactically guided fractionated radiotherapy: technical aspects. Radiother Oncol. 1993;29:197-204.
7. **Bortfeld T**, Boyer AL, Schlegel W, Kahler DL, Waldron TJ. Realization and Verification of 3-Dimensional Conformal Radiotherapy with Modulated Fields. Int J Radiat Oncol Biol Phys. 1994;30:899-908.
8. **Bortfeld T**, Schlegel W, Stein J, Preiser K. Intensitätsmodulation und inverse Planung: von der Theorie zum Phantomexperiment [Tagungsbericht]. Z Med Phys. 1994;4:105-6.
9. **Bortfeld T**, Kahler DL, Waldron TJ, Boyer AL. X-ray field compensation with multileaf collimators. Int J Radiat Oncol Biol Phys. 1994;28:723-30.
10. Gardey KU, **Bortfeld T**, Schlegel W, Rhein B. Einfluss von Näherungen auf die schnelle 3-D Dosisberechnung irregulärer Felder in der stereotaktischen Konvergenzbestrahlung. Z Med Phys. 1994;4:84-9.
11. Mohan R, Wang XH, Jackson A, **Bortfeld T**, Boyer AL, Kutcher GJ, Leibel SA, Fuks Z, Ling CC. The potential and limitations of the inverse radiotherapy technique. Radiother Oncol. 1994;32:232-48.
12. Stein J, **Bortfeld T**, Doerschel B, Schlegel W. Dynamic x-ray compensation for conformal radiotherapy by means of multi-leaf collimation. Radiother Oncol. 1994;32:163-73.
13. **Bortfeld T**, Boyer AL. The Exponential Radon Transform and Projection Filtering in Radiotherapy Planning. Int J Imag Syst Techn. 1995;6:62-70.
14. **Bortfeld T**, Dinter W. Calculation of Multidimensional Hartley Transforms Using One-Dimensional Fourier-Transforms. IEEE Trans Signal Process. 1995;43:1306-10.
15. Chen Z, Wang XH, **Bortfeld T**, Mohan R, Reinstein LE. The influence of scatter on the design of optimized intensity modulations. Med Phys. 1995;22:1727-33.

16. **Bortfeld T**, Schlegel W. An Analytical Approximation of Depth-Dose Distributions for Therapeutic Proton-Beams. Phys Med Biol. 1996;41:1331-9.
17. Dykstra C, **Bortfeld T**, Debus J, Lomax A, Harrop R, Schlegel W, Munkel G. Characterization of dose distribution in radiation therapy plans. Radiother Oncol. 1996;41:281-4.
18. Ling CC, Burman C, Chui CS, Kutcher GJ, Leibel SA, LoSasso T, Mohan R, **Bortfeld T**, Reinstein LE, Spirou S, Wang XH, Wu Q, Zelefsky M, Fuks Z. Conformal radiation treatment of prostate cancer using inversely-planned intensity-modulated photon beams produced with dynamic multileaf collimation. Int J Radiat Oncol Biol Phys. 1996;35:721-30.
19. **Bortfeld T**. An Analytical Approximation of the Bragg Curve for Therapeutic Proton Beams. Med Phys. 1997;24:2024-33.
20. Debus J, Engenhart-Cabillic R, Holz FG, Pastyr O, Rhein B, **Bortfeld T**. Stereotactic precision radiotherapy in the treatment of intraocular malignancies with a micro-multileaf collimator. Frontiers in Radiation Therapy and Oncology. 1997;30:39-46.
21. Ésik O, **Bortfeld T**, Bendl R, Németh G, Schlegel W. Inverse Radiotherapy Planning for a Concave-Convex PTV in Cervical and Upper Mediastinal Regions. Strahlenther Onkol. 1997;173:193-200.
22. Gardey KU, **Bortfeld T**, Schlegel W, Rhein B. A Fast Algorithm for the Dose Calculation of Irregularly Shaped Fields in Stereotactic Convergent Beam Irradiation. Phys Med Biol. 1997;42:717-24.
23. Miralbell R, Lomax A, **Bortfeld T**, Rouzaud M, Carrie C. Potential Role of Proton Therapy in the Treatment of Medulloblastoma / Primitive Neuro-Ectodermal Tumors: Reduction of the Supratentorial Target Volume. Int J Radiat Oncol Biol Phys. 1997;38:477-84.
24. Stein J, Mohan R, Wang XH, **Bortfeld T**, Wu Q, Preiser K, Ling CC, Schlegel W. Number and Orientations of Beams in Intensity-Modulated Radiation Treatments. Med Phys. 1997;24:149-60.
25. Webb S, **Bortfeld T**, Stein J, Convery D. The effect of stair-step leaf transmission on the 'tongue-and-groove problem' in dynamic radiotherapy with a multileaf collimator. Phys Med Biol. 1997;42:595-602.
26. Debus J, Fuss M, Engenhart-Cabillic R, Holz F, Pastyr O, Rhein B, **Bortfeld T**, Wannenmacher M. Stereotaktische konformierende Bestrahlung von Aderhautmetastasen. Der Ophtalmologe. 1998;95:163-57.
27. Preiser K, **Bortfeld T**, Hartwig K, Schlegel W, Stein J. Inverse Strahlentherapieplanung für intensitätsmodulierte Photonenfelder. Radiologe. 1998;38:228-34.
28. **Bortfeld T**, Oelfke U. Fast and exact 2D image reconstruction by means of Chebyshev decomposition and backprojection. Phys Med Biol. 1999;44:1105-20.
29. **Bortfeld T**. Optimized planning using physical objectives and constraints. Seminars in Radiation Oncology. 1999;9:20-34.
30. Keller-Reichenbecher M-A, **Bortfeld T**, Levegrün S, Stein J, Preiser K, Schlegel W. Intensity modulation with the "step and shoot" technique using a commercial mlc: planning study. Int J Radiat Oncol Biol Phys. 1999;45:1315-24.
31. Lomax AJ, **Bortfeld T**, Goitein G, Debus J, Dykstra C, Tercier P, Coucke PA, Mirimanoff RO. A treatment planning inter-comparison of proton and intensity modulated photon radiotherapy. Radiother Oncol. 1999;51:257-71.

32. Oelfke U, **Bortfeld T**. Inverse planning for x-ray rotation therapy: a general solution of the Inverse Problem. Phys Med Biol. 1999;44:1089-104.

33. **Bortfeld T**, Oelfke U, Nill S. What is the optimum leaf width of a multileaf collimator? Med Phys. 2000;27:2494-502.

34. Oelfke U, **Bortfeld T**. Intensity modulated radiotherapy with charged particle beams: Studies of inverse treatment planning for rotation therapy. Med Phys. 2000;27:1246-57.

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41. Spies L, Partridge M, Groh BA, **Bortfeld T**. An iterative algorithm for reconstructing incident beam distributions from transmission measurements using electronic portal imaging. Phys Med Biol. 2001; 46:N203-N211.

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43. Thieke C, **Bortfeld T**, Kufer K-H. Characterization of dose distributions through the max and mean dose concept. Acta Oncologica. 2002;41:158-161.

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Professional educational materials or reports, in print or other media:

1. A pioneering approach to cancer treatment (Video, Institute of Physics, Physics World) https://physicsworld.com/a/a-pioneering-approach-to-cancer-treatment/ 2013.
2. Targeting tumors (Video, Institute of Physics, Physics World) https://physicsworld.com/a/targeting-tumours/ 2013.
3. Proton therapy teams up with PET imaging (Video, Institute of Physics, Physics World) https://physicsworld.com/a/proton-therapy-teams-up-with-pet-imaging/ 2013.
4. Fighting cancer with mathematics (Video, Institute of Physics, Physics World) https://physicsworld.com/a/fighting-cancer-with-mathematics/ 2013.
5. **Bortfeld T**, Orton C. AAPM Virtual Museum of Medical Physics: Gallery 13, Computerized Treatment Planning and the Development of Modern External Beam Radiotherapy. https://museum.aapm.org/exhibit/13-treatment-planning-and-the-development-of-modern-external-beam-radiotherapy/ 2020.

Thesis:

1. **Bortfeld T**. 3-D Aufnahme und Rekonstruktion lichtmikroskopischer Zellkernbilder [diploma thesis]. Heidelberg University; 1988.
2. **Bortfeld T**. Neue Methoden zur Lösung des inversen Problems der Strahlentherapieplanung [PhD dissertation]. Heidelberg University; 1990.
3. **Bortfeld T**. Dosiskonformation in der Tumortherapie mit externer ionisierender Strahlung: Physikalische Möglichkeiten und Grenzen [habilitation]. Heidelberg University; 1995.

Narrative Report

I am a Medical Physicist with a passion for research and development to solve clinical problems, deploying the resulting innovative technologies in the clinic, and translating new problems that arise in the clinic back into research questions. I made this transition of technologies from the bench to the bedside and back many times throughout my career.

Investigation and Clinical Innovation

My core area of excellence is investigation. Starting with my PhD thesis project at the University of Heidelberg and the German Cancer Research Center, I have been instrumental in the early development and in the later refinement of intensity-modulated radiation therapy (IMRT). The primary tools in conducting my research have included methods from computer science and mathematical optimization (Operations Research, OR). While I initially developed the tools primarily within my own team, I have later started to collaborate closely with Medical Physicists around the world, leading experts in Operations Research, several companies, and of course Radiation Oncologists. Within these multi-disciplinary collaborations, we developed IMRT planning and delivery, multi-criteria plan optimization and robust optimization, and translated them into the clinics worldwide. IMRT delivered with multileaf collimators and optimized inverse planning as rooted in my earlier work have since become the state-of-the-art in modern Radiation Oncology with over 30 million patients treated and approximately 2.5 million quality-adjusted life years gained.
My current areas of interest are the optimization of the clinical target volume (CTV) definition, optimized personalized sequencing/fractionation of radiation treatments in combination with other treatment modalities, and the democratization of proton therapy.
In addition to Operations Research tools, my "toolbox" includes imaging methods and nuclear physics methods for image guidance and for controlling the range of proton beams in the patient, all with the common goal of delivering radiation more precisely.

Teaching and Administration

One of my most rewarding professional experiences has been to inspire students and young faculty, to be then inspired by their insights and ideas, shaping our field moving forward. I enjoy classroom teaching and conference presentations as much as one-on one teaching and mentoring. As a result of my dedication to teaching, I completed my "habilitation" at the University of Heidelberg – a prerequisite for becoming a university teacher and professor in Germany. Because of my desire to attract students from the Physics Department to Medical Physics, I was one of the first Medical Physicists who did their habilitation in the Physics Department, not the Medical School. I am strongly convinced that the field of Medical Physics needs both, the clinical focus, which always comes first, but also the strong scientific foundation. Together with my colleague Robert Jeraj I have worked on this clinic-research balance as co-chair of the Working Group Future of the American Association of Physicists in Medicine (AAPM), the European Society for Radiotherapy and Oncology (ESTRO), and the Topical Group on Medical Physics of the American Physical Society (APS). I am working hard on creating and maintaining an inspiring clinical-translational-research spirit also in my role as the Division Chief of Radiation Biophysics at the Massachusetts General Hospital.