Date Prepared: **01/11/2015**

Name: **Jan Unkelbach**

Office Address: **Burr Proton Therapy Center, 30 Fruit Street, Boston MA 02114**

Home Address: **7 Westley Ave, Cambridge MA 02140**

Work Phone: **617-643-6690**

Work Email: **junkelbach@partners.org**

Place of Birth: **Darmstadt, Germany**

Education

2000	BSc (first class)	Physics	University of Manchester UMIST, UK
2002	Diplom (MSc) (summa cum laude)	Physics	Technical University Berlin, Germany
2006	PhD (summa cum laude)	Physics (Prof. U. Oelfke)	University of Heidelberg, Germany

Postdoctoral Training

07/06-06/08	Postdoc	Medical Physics (Prof. T. Bortfeld)	Massachusetts General Hospital, Boston, MA, USA
08/08-11/09	Postdoc	Machine Learning (Prof. J. Schmidhuber)	Istituto Dalle Molle di Studi sull'intelligenza artificiale (IDSIA), Lugano, Switzerland

Faculty Academic Appointments

09/10-	Assistant Professor	Radiation Oncology	Harvard Medical School

Appointments at Hospitals/Affiliated Institutions

11/02-06/06	Researcher	Department of Medical Physics in Radiation Therapy	German Cancer Research Center, Heidelberg, Germany
07/06-06/08	Postdoctoral Fellow	Department of Radiation Oncology	Massachusetts General Hospital, Boston, MA
02/10-	Assistant Radiation Physicist	Department of Radiation Oncology	Massachusetts General Hospital, Boston, MA

Committee Service

National and International

2010-2014	Member of the task group TG-202: Physical Uncertainties in the Planning and Delivery	American Association of Physicists in Medicine (AAPM)

	of Light Ion Therapy	
2012-	Member of the abstract selection committee of the AAPM annual meeting	American Association of Physicists in Medicine (AAPM)
2014-	Member of the AAPM seed funding review panel	American Association of Physicists in Medicine (AAPM)
2006-	Reviewer for the main journals	Physics in Medicine Biology Medical Physics Int. J. Rad. Oncology, Biology, Physics Radiotherapy & Oncology Medical Image Analysis

Professional Societies

2002-	Deutsche Physikalische Gesellschaft (DPG)	Member
2010-	American Association of Physicists in Medicine (AAPM)	Member
2012-2014	Medical Image Computing and Computer Assisted Interventions (MICCAI)	Member
2012-2014	Institute of Operation Research and the Management Sciences (INFORMS)	Member

Honors and Prizes

2000	Best Final Year Computational Project Award	University of Manchester, UK
2002	Completed MSc Degree with summa cum laude	Technical University Berlin, Germany
2004	Young Investigators Award for outstanding research paper	ICCR Congress, Seoul, South Korea
2006	Completed PhD Degree with summa cum laude	University of Heidelberg, Germany
2010	Travel fellowship PTCOG Conference, Maebashi, Japan	Particle Therapy Cooperative Group (PTCOG)
2013	Best in Physics award at AAPM annual meeting, Indianapolis	American Association of Physicists in Medicine (AAPM)

Report of Funded and Unfunded Projects

Funding Information

Past

2006-2008	Proton Radiotherapy optimization Industry collaboration with Siemens Medical Systems Co-Investigator

Goal of the project was to develop robust optimization methods for handling uncertainty in proton therapy planning

2011-2013 Radiotherapy planning for glioblastoma based on a tumor growth model
MGH Spiro Grant Award
PI ($88,500)
Goal of the project is to develop a phenomenological tumor growth model for radiotherapy planning of gliomas in order to account for anisotropic infiltrative spread of disease

2011-2013 Improving treatment planning for glioblastoma
NIH NCI / Federal Share of program income (C06 CA059267)
PI ($572,600)
Goal of the project is to improve radiotherapy for high grade gliomas by modeling the spatio-temporal growth patterns and response to radiation

2010-2014 Proton Radiation Therapy Research
NIH NCI (P01 CA21239)
Co-Investigator
Goal of the project is to optimize planning and delivery of proton therapy

Current

2010-2016 Optimizing the parameters of external beam radiation therapy
Industry collaboration with Philips Medical Systems
Co-Investigator
Goal of the project is to advance optimization methods for radiotherapy treatment planning using photon and proton beams

2014-2019 Therapy Imaging Program
NIH NCI (C06 CA059267)
Co-Investigator
The goal of this project is to advance the state of the art in imaging for particle therapy for more accurate target definition, dose verification, and response assessment.

2014-2019 Improving the Clinical Effectiveness and Understanding of the Biophysical Basis of Proton Therapy
NIH NCI (U19 CA021239-35)
Co-Investigator
The main goals of this project include research and development related to intensity-modulated proton therapy (IMPT) and its application in clinical trials.

Current Unfunded Projects

2012- Investigator and Supervisor / Optimal fractionation in radiotherapy
Goal of the project is to optimize fractionation schemes in radiotherapy, accounting for radiobiological factors and the spatial dose distribution.

2013- Investigator / Split-course radiotherapy for large liver tumors
Goal of the project is to explore the potential for split-course radiotherapy for liver tumors, motivated by tumor shrinkage over the treatment break, which allows for smaller treatment fields in the second stage.

Report of Local Teaching and Training

Teaching of Students in Courses

2007	Physics in Radiation Oncology – sharpening the Edge (HST.187) Graduate students of physics and nuclear engineering	Health Science Technology (HST) at Harvard/MIT Lecturer (taught two 2-hr sessions)
2008	Intelligent Systems Graduate students of computer science	University of Lugano, Switzerland Lecturer / Course design (4-hr sessions per week for 6 weeks)
2010	Online Master Advanced Medical Physics Graduate students of physics	University of Heidelberg, Germany Lecturer (taught one 2-hr session)
2011/ 2012/ 2014	Medical Physics of proton radiation therapy (HST.531) Graduate students of physics and nuclear engineering	Health Science Technology (HST) at Harvard/MIT Instructor, responsible for course design (2-hr sessions per week for 12 weeks)
2013/ 2015	Optimization problems in Radiation therapy and medical imaging (HST.533) Graduate students of physics and computer science	Health Science Technology (HST) at Harvard/MIT Instructor, responsible for course design (2-hr sessions per week for 12 weeks)

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

2003-2005	Physics Lab Radiotherapy technicians	Klinikum Ludwigshafen (designed and instructed a physics lab, 4-hr sessions per week for 10 weeks)
2008	Residency program Medical physics residents	Massachusetts General Hospital (taught one 2-hr session)

Laboratory and Other Research Supervisory and Training Responsibilities

2004-2005	Supervision of Masters student (Daniel Maleike) / German Cancer Research Center	12 months
2006-2008	Supervision of PhD student (Benjamin Martin) / Massachusetts General Hospital	24 months
2011-2012	Supervision of Postdoc (Ali Motamedi) Massachusetts General Hospital	10 months
2012	Supervision of Postdoc (Andrea Cassioli) Massachusetts General Hospital	9 months
2012-2013	Supervision of Masters student (Florian Dittmann) Massachusetts General Hospital	12 months
2012-2013	Supervision of PhD student (Jagdish Ramakrishnan) Massachusetts General Hospital	24 months
2012-2013	Supervision of Postdoc (Ehsan Salari) / Massachusetts General Hospital	18 months

2013-2014	Supervision of Postdoc (David Papp) / Massachusetts General Hospital	18 months
2013-	Supervision of PhD student (Matthieu Le) Massachusetts General Hospital	
2014-	Supervision of Postdoc (Bram Gorissen) / Massachusetts General Hospital	
2014-	Supervision of Masters student (Ryan King) / Massachusetts General Hospital	
2015-	Supervision of Masters student (Teun Minkels) / Massachusetts General Hospital	
2015-	Supervision of Postdoc (Zoltan Perko) / Massachusetts General Hospital	

Local Invited Presentations

2006-2015 More than 15 presentations in seminars and journal clubs

Report of Regional, National and International Invited Teaching and Presentations

Invited Presentations and Courses

National

2007	Reducing the sensitivity of IMPT treatment plans to setup errors and range variations AAPM annual meeting, Minneapolis, MN (proffered abstract)
2008	Why the safety margin concept is insufficient in particle therapy PTCOG conference, Jacksonville, FL (proffered abstract)
2010	Handling range uncertainty and setup errors in intensity modulated proton therapy Philips Medical Systems / University of Wisconsin-Madison (invited seminar presentation)
2011	Intensity modulated proton therapy and the range uncertainty problem Radiation therapy symposium, Purdue University, Indiana (invited workshop presentation)
2012	Imaging based treatment plan optimization for glioblastoma INFORMS conference, Phoenix, AZ (invited symposium presentation)
2012	Accounting for anisotropic growth of glioma in radiotherapy planning AAPM annual meeting (proffered abstract)
2013	Simultaneous optimization of dose distributions and fractionation schemes based on the BED model, INFORMS HEALTHCARE conference, Chicago, IL
2013	The emergence of non-uniform spatio-temporal fractionation schemes within the standard BED model, AAPM annual meeting, Inianapolis, IN (Best in Physics distinction).
2014	Combined temporal and spatial treatment optimization SIAM OPT meeting, San Diego, CA (invited symposium presentation)
2014	Exploiting tumor shrinkage in split-course radiotherapy AAPM annual meeting, Austin, TX (proffered abstract)
2014	Robust optimization – The status of intensity-modulated proton therapy AAPM annual meeting, Austin, TX (invited symposium presentation)
2015	Radiotherapy treatment planning based on the biologically equivalent dose model

Mathematical Bioscience Institute (MBI), Columbus, OH (invited workshop presentation)

International

2004 Organ movements in IMRT treatment planning: inverse planning based on probability distributions. ICCR conference, Seoul, South Korea (proffered paper)

2005 A concept for the estimation of dose uncertainties caused by respiratory motion in radiotherapy. ESTRO conference, Lisbon, Portugal (proffered abstract)

2007 Handling range uncertainty in IMPT optimization
ICCR conference, Toronto, Canada (proffered paper)

2007 Including geometrical uncertainties in IMRT and IMPT optimization
ESTRO conference, Barcelona, Spain (invited symposium talk)

2008 Operations Research in Radiotherapy Treatment planning
Reykjavik University, Iceland (invited seminar presentation)

2008 Mathematical Optimization in Radiotherapy Treatment planning
Informatics Faculty, Technical University Munich, Germany
(invited seminar presentation)

2009 Range, setup and dose calculation errors in IMPT and their interrelation
World Congress Biom. Eng. Med. Phys., Munich, Germany (proffered paper)

2009 An EM based training algorithm for recurrent neural networks
ICANN conference, Limassol, Cyprus (proffered paper)

2010 Robust treatment plan optimization for handling range uncertainty in intensity modulated proton therapy. PTCOG conference, Japan (proffered abstract)

2010 Robustness of a treatment plan
ESTRO conference, Barcelona, Spain (invited symposium talk)

2010 Inverse planning and optimization – opening the black box
ESTRO conference, Barcelona, Spain (invited teaching lecture)

2011 Treatment planning for glioblastoma based on a computational tumor growth model
AAPM annual meeting, Vancouver, CA (proffered abstract)

2011 Stochastic programming methods for handling uncertainty in treatment plan optimization
Summer workshop for Image guided and Robotic Radiotherapy, Mannheim, Germany
(invited workshop presentation)

2011 Radiotherapy planning for glioblastoma based on a computational tumor growth model
Paul Scherer Institute (PSI), Villingen, Switzerland (invited seminar presentation)

2011 Mathematical methods in radiation therapy
Computer Vision Lab, ETH Zurich, Switzerland (invited seminar presentation)

2012 Automated tumor segmentation for radiotherapy planning
MICCAI workshop BRATS, Nice, France (invited symposium presentation)

2012 Glioblastoma growth modeling for radiotherapy target delineation
MICCAI workshop IGRT, Nice, France (proffered paper)

2012 Radiation therapy planning
Asclepios Project, INRIA Sophia Antipolis, France (invited seminar presentation)

2014 Data based spatiotemporal radiotherapy planning
German Cancer Research Center, Germany (invited seminar presentation)

Report of Scholarship

Summary

Number of peer-reviewed publications:	38	(20 first author, 8 senior author, 10 coauthor)
Scientific journal papers:	26	
Conference papers:	9	
Review papers:	3	
Total number of citations:	695	(Google scholar, March 2015)
H-index:	13	
Book chapters:	5	
Conference abstracts:	37	
as first author	15	
as coauthor	22	
Oral presentations at major conferences:	21	

Publications

Peer reviewed publications in print or other media

Peer-reviewed journal publications:

1. E. Schöll, A. Amann, M. Rudolf, J. Unkelbach. Transverse spatio-temporal instabilities in the double barrier resonant tunneling diode. Physica B, 2002;314:113--117.

2. J. Unkelbach , A. Amann, W. Just, E. Schöll. Time-delay autosynronization of spatiotemporal dynamics in resonant tunneling diodes. Physical Review E, 2003;68(2):026204.

3. J. Unkelbach and U.~Oelfke. Inclusion of organ movements in IMRT treatment planning via inverse planning based on probability distributions. Phys. Med. Biol.2004;49:4005--29.

4. S. Nill, J. Unkelbach, L. Dietrich, U. Oelfke. Online correction for respiratory motion: evaluation of two imaging geometries. Phys. Med. Biol. 2005;50:4087--4096.

5. J. Unkelbach and U. Oelfke. Incorporating organ movements in IMRT treatment planning for prostate cancer: Minimizing uncertainties in the inverse planning process. Med. Phys.2005;32:2471--83.

6. J. Unkelbach and U. Oelfke. Incorporating organ movements in inverse planning: assessing dose uncertainties by Bayesian inference. Phys. Med. Biol. 2005;50:121--139.

7. D. Maleike, J. Unkelbach, U. Oelfke. Simulation and visualization of dose uncertainties due to interfractional organ motion. Phys. Med. Biol. 2006;51:2237--2252.

8. J. Unkelbach and U. Oelfke. Relating two techniques for handling uncertainties in IMRT optimization. Phys. Med. Biol. 2006;51:N423--N427.

9. C. Thilmann, P. Häring, L. Thilmann, J. Unkelbach, B. Rhein, S. Nill, P. Huber, E. Janisch, C. Thieke, and J. Debus. The influence of breathing motion on intensity modulated radiotherapy in the step-and-shoot technique: phantom measurements for irradiation of superficial target volumes. Phys. Med. Biol. 2006;51:N117--N126.

10. J. Unkelbach , T. C. Y. Chan, T. Bortfeld. Accounting for range uncertainties in the optimization of intensity modulated proton therapy. Phys. Med. Biol. 2007;52:2755--2773.

11. J. Unkelbach, B. Martin, M. Soukup, and T. Bortfeld. Reducing the sensitivity of IMPT treatment plans to setup errors and range uncertainties via probabilistic treatment planning. Medical Physics. 2009;36:149--163

12. E. Heath, J. Unkelbach, U. Oelfke. Incorporating uncertainties in respiratory motion into 4D treatment plan optimization. Medical Physics. 2009;36:3059—3071.

13. A. Trofimov, J. Unkelbach, T. DeLaney, and T. Bortfeld. Visualization of a variety of possible dosimetric outcomes in radiation therapy using dose-volume histogram bands. Practical radiation oncology. 2012; 2(3):164-171

14. W. Chen, J. Unkelbach, A. Trofimov, T. Madden, H. Kooy, T. Bortfeld, and D. Craft. Including robustness in multi-criteria optimization for intensity-modulated radiotherapy. Phys. Med. Biol. 2012; 57(3):591-608

15. Unkelbach J, Craft D, Salari E, Ramakrishnan J, and Bortfeld T. The dependence of optimal fractionation schemes on the spatial dose distribution. Phys. Med. Biol. 2013; 58(1):159-167

16. Cassioli A and Unkelbach J. Aperture shape optimization for IMRT treatment planning. Phys. Med. Biol. 2013; 58(2):301-18

17. Salari E and Unkelbach J. A column-generation based technique for multi-criteria direct aperture optimization. Phys. Med. Biol. 2013; 58:621-39

18. J. Unkelbach, C. Zeng, and M. Engelsman.Simultaneous optimization of dose distributions and fractionation schemes in particle radiotherapy. Med. Phys. 2013; 40(9):091702.

19. J. Unkelbach, B. H. Menze, E. Konukoglu, F. Dittmann, M. Le, N. Ayache, and H. Shih. Radiotherapy planning for glioblastoma based on a tumor growth model: improving target volume delineation. Phys. Med. Biol., 2014; 59(3):747-770.

20. J. Unkelbach, B. H. Menze, E. Konukoglu, F. Dittmann, N. Ayache, and H. Shih. Radiotherapy planning for glioblastoma based on a tumor growth model: implications for spatial dose redistribution. Phys. Med. Biol., 2014; 59(3):771-790

21. D. Craft, D. Papp, and J. Unkelbach. Plan averaging for multicriteria navigation of sliding window IMRT and VMAT. Medical Physics, 2014; 41:021709.

22. D. Papp and J. Unkelbach. Direct leaf trajectory optimization for volumetric modulated arc therapy with sliding window delivery. Medical Physics, 2014; 41:011701.

23. J. Unkelbach, D. Craft, T. Hong, D. Papp, J. Ramakrishnan, E. Salari, J. Wolfgang, and T. Bortfeld. Exploiting tumor shrinkage through temporal optimization of radiotherapy. Phys. Med. Biol., 2014; 59(12):3059-3079.

24. D. Craft, M. Bangert, T. Long, D. Papp, J. Unkelbach. Shared data for intensity modulated radiation therapy (IMRT) optimization research: the CORT dataset. GigaScience, 2014; 3:37.

25. E. Salari, J. Unkelbach, T. Bortfeld. A Mathematical Programming Approach to the Fractionation Problem in Chemoradiotherapy. IIE Trans. on Healthcare Sys. Eng., 2015 (in press, preprint available on arXiv)

26. J. Unkelbach, D. Papp. The emergence of nonuniform spatiotemporal fractionation schemes within the standard BED model. Med. Phys., 2015 (in press)

Peer-reviewed conference papers:

27. J. Unkelbach and U. Oelfke. Organ movements in IMRT treatment planning: inverse planning based on probability distributions. In Proc. 14th Int. Conf. on the Use of Computers in Radiation Therapy, Seoul, South Korea, 2004, p104-107.

(Young investigator's award)

28. J. Unkelbach, T. C. Y. Chan, and T. Bortfeld. Handling range uncertainty in IMPT optimization. In J. Bissonnette et al (editors), Proc. 15th Int. Conf. on the Use of Computers in Radiation Therapy, Volume 2, 2007, p561-565.

29. J. Unkelbach, Sun Yi, J. Schmidhuber. An EM based training algorithm for recurrent neural networks. In Alippi et al (editors) ICANN 2009, Part I, Lecture Notes in Comp. Sci. 5768, p964-974, 2009

30. J. Unkelbach, M. Soukup, M. Alber, and T. Bortfeld. Range, setup and dose calculation errors in IMPT and their interrelation. In Dössel et al (editors), World Congress on Medical Physics and Biomedical Engineering, IFMBE Vol 25/1, 2009; p900--903

31. J. Unkelbach, B. Menze, A. Motamedi, F. Dittmann, E. Konukoglu, N. Ayache, and H. Shih. Glioma growth modeling for radiotherapy target delineation. MICCAI workshop on Multimodal imaging in radiotherapy. 2012 (available at http://hal.archives-ouvertes.fr/hal-00755222)

32. F. Dittmann, B. Menze, E. Konukoglu, J. Unkelbach. Use of Diffusion Tensor Images in Glioma Growth Modeling for Radiotherapy Target Delineation. In L. Shen et al (editors), Multimodal Brain Image Analysis (Proc. MICCAI workshop MBIA), Lecture Notes in Comp. Sci. 8159, p63-73, 2013.

33. M. Le, H. Delingette, J. Kalpathy-Cramer, E. Gerstner, H. A. Shih, T. Batchelor, J. Unkelbach, and N. Ayache. Multimodal Analysis of Vasogenic Edema in Glioblastoma Patients for Radiotherapy Planning. The MIDAS Journal (Proc. MICCAI workshop IGART)}, 2014. (available at http://hdl.handle.net/10380/3500)

34. J. Unkelbach. Non-uniform spatiotemporal fractionation schemes in photon radiotherapy. IFMBE Proc. World Cong. on Med. Phys. Biomed. Eng.}, Springer, 2015. (accepted)

35. M. Bangert and J. Unkelbach. Objective function surrogates for iterative beam angle selection. IFMBE Proc. World Cong. on Med. Phys. Biomed. Eng.}, Springer, 2015. (accepted)

Peer-reviewed review articles:

36. C. Orton, T. Bortfeld, A. Niemierko, J. Unkelbach. The role of medical physicists and the AAPM in the development of treatment planning and optimization; Medical Physics. 2008;35:

37. Y. Censor and J. Unkelbach. From analytic inversion to contemporary IMRT optimization: radiation therapy revisited from a mathematical perspective. Physica Medica. 28(2):109–118, 2012

38. J. Unkelbach, M. Alber, M. Bangert, et al. Optimization approaches to volumetric modulated arc therapy planning. Medical Physics, 2015 (in press)

Non-peer reviewed scientific or medical publications/materials in print or other media

Book chapters

1. A. Trofimov, J. Unkelbach, and D. Craft. Treatment planning optimization, in H. Paganetti (editor), Proton therapy physics (Chapter 15)}, CRC Press, 2012.

2. D. McQuaid, J. Unkelbach, A. Trofimov, and T. Bortfeld. Robust optimization, in J. R. Palta et al (editor), Uncertainties in External Beam Radiation Therapy (Chaper 11), Medical Physics Publishing, 2011

3. A. Boyer and J. Unkelbach. Intensity-modulated radiation therapy planning. in A. Brahme (editor), Comprehensive Biomedical Physics (Volume 9) - Radiation Therapy Physics and Treatment Planning (Chapter 14), Elsevier, 2014

In press: J. Unkelbach, D. Craft, B.Gorissen, T. Bortfeld. Plan Optimization. in I. Das and H. Paganetti (editors), Principles and Practice of Proton Beam Therapy (Chapter 22), Medical Physics Publishing, 2015

In press: J. Unkelbach. Intensity-modulated radiation therapy: Photons. in F. Khan et al (editors), Treatment Planning in Radiation Oncology, 4th edition (Chapter 10).

Thesis

1. J. Unkelbach. Rückkopplungsgesteuerte transversale Dynamik der resonanten Tunneldiode. Master's thesis, Technische Universität Berlin, 2002, (in german, available on request).

2. J. Unkelbach. Inclusion of organ motion in IMRT optimization using probabilistic treatment planning. PhD thesis, University of Heidelberg, 2006, (available at http://www.ub.uni-heidelberg.de/archiv/6139/).

Abstracts, Poster Presentations and Exhibits Presented at Professional Meetings

Conference abstracts:

1. J. Unkelbach, U.Oelfke. Inclusion of stochastic organ movements in IMRT treatment planning. Radio. Onc. 2003;68:S101-102.

2. J. Unkelbach, U.Oelfke. Inverse planning incorporating organ movements via probability distributions of voxel locations. Radio. Onc. 2004;73:S347.

3. J. Unkelbach, U.Oelfke. A concept for the estimation of dose uncertainties caused by respiratory motion in radiotherapy. Radio. Onc. 2005;76:S93.

4. J. Unkelbach, D. Maleike, U.Oelfke. On Probabilistic Treatment Planning: A Novel Concept for Including Organ Motion Into IMRT Optimization. Med. Phys. 2005;32(6):1976.

5. S. Nill, J. Unkelbach, L. Dietrich, U. Oelfke. Evaluation of Two Fluoroscopic Imaging Setups for Online Dose Delivery Adaptation. Med. Phys. 2005;32(6):1933.

6. R. Flynn, J. Unkelbach, U. Oelfke, R. Jeraj, T. Mackie. A comparison of two probabilistic methods for intrafractional re-optimization in IMRT. Radio. Onc. 2005;73:S106-107

7. S. Nill, L. Dietrich, J. Unkelbach, U. Oelfke. Adaptive radiotherapy (ART) of organ motion: evaluation of two imaging concepts. Radio. Onc. 2005;73:S106-107

8. J. Unkelbach, D. Craft, T. Halabi, T. Bortfeld, U. Oelfke. A Mixed Integer Formulation for Direct Aperture Optimization of IMRT. Med. Phys. 2006;33(6):2055.

9. J. Unkelbach, T. C. Y. Chan, and T. Bortfeld. Reducing the sensitivity of IMPT treatment plans to setup errors and range variations. Med. Phys. 2007;34(6):2523.

10. T. Bortfeld, G. Chen, H. Paganetti, J. Unkelbach, M. Engelsman. The Good and the Not-So-Good of the Finite Proton Range. Med. Phys. 2007;34(6):2552.

11. T. Bortfeld, A. Trofimov, J. Unkelbach, T.C.Y. Chan, and B. Martin. Patient motion: Adaptive Radiotherapy. Med. Phys. 2007;34(6):2584.

12. S. Safai, T. Bortfeld, M. Engelsman, J. Unkelbach, A. Trofimov. The limitation of the patching technique in 3D conformal proton radiotherapy (3DCPT) and the benefits of IMPT. Radio. Onc. 2007;84:S130

13. J. Unkelbach. Including geometrical uncertainties in IMRT and IMPT optimization. Radio. Onc. 2007;84:S90

14. J. Unkelbach, B. Martin, and T. Bortfeld. Why the safety margin concept is insufficient in particle therapy. Proc. PTCOG, Jacksonville, FL, USA, 2008.

15. S. Safai, T. Bortfeld, M. Engelsman, J. Unkelbach, A. Trofimov, J. Adams. Is IMPT still superior to 3D conformal proton therapy in the presence of setup errors and range uncertainties. Proc. PTCOG, Jacksonville, FL, USA, 2008.

16. E. Heath, J. Unkelbach and U. Oelfke, Incorporating uncertainties in respiratory motion into treatment plan optimization, Proc. ESTRO meeting on Physics and Radiation Technology for clinical radiotherapy, Gothenberg, Sweden, 2008.

17. J. Unkelbach, B. Martin, and T. Bortfeld. Design of a Next Generation Treatment Planning System That Incorporates Motion and Uncertainty in Inverse Planning. Med. Phys. 2008;35(6):2753.

18. B. Martin, J. Unkelbach, D. Castanon, and T. Bortfeld. Incorporating uncertainty in radiation therapy optimization with scenario and voxel sampling. Med. Phys. 2008;35(6):2754.

19. T. Bortfeld, A. Trofimov, J. Unkelbach, B. Martin,, and O. Nohadani. Patient Motion & 4D inverse planning. Med. Phys. 2008;35(6):2929.

20. J. Kang, J. Unkelbach, A. Trofimov, and T. Bortfeld. Implementation of a dose delivery model to handle respiratory motion with variability. Med. Phys. 2009;26(6):3059.

21. A. Trofimov, P.L. Nguyen, M.W. Lu, J. Unkelbach, J. Kang, T. Bortfeld, and A.L. Zietman. Feasibility of Hemi-prostate dose escalation to 91 Gy with 3D-conformal vs. intensity-modulated proton therapy. Int. J. Rad. Onc. Biol. Phys. 2009;75(3)(Sup 1):703-4.

22. J. Unkelbach, M. Soukup, and T. Bortfeld. Robust treatment plan optimization for handling range uncertainty in intensity modulated proton therapy. Proc. PTCOG, Maebashi, Japan, 2010

23. A. Trofimov, J. Kang, J. Unkelbach, J. Adams, X. Zhang, T. Bortfeld, N. Liebsch, T. DeLaney. Evaluation of dosimetric gain and uncertainties in proton therapy delivery with scanned pencil beam in treatment of base-of-skull and spinal tumors. Int. J. Rad. Onc. Biol. Phys. 2010;78(3):S133-134

24. J. Unkelbach, B. Menze, E. Konukoglu, H. Shih, N. Ayache, and T. Bortfeld. Treatment planning for glioblastoma based on a computational tumor growth model. Med. Phys. 2011;38(6):3827

25. J. Unkelbach, B. Menze, A. Motamedi, E. Konukoglu, N. Ayache, and H. Shih. Accounting for anisotropic growth of glioma in radiotherapy planning. Med. Phys. 2012;39(6):3602

26. W. Chen, J. Unkelbach, A. Trofimov, T. Madden, H. Kooy, T. Bortfeld, D. Craft. Robust Multi-Criteria IMPT Optimization. Med. Phys. 2012;39(6):3981

27. T. Bortfeld, D. Craft, W. Chen, A. Trofimov, C. Richter, J. Seco, J. Ramakrishnan, J. Unkelbach. Treatment Planning: Integrating robustness in optimization. Radio. Onc. 2012;103:S7

28. D. Papp, J. Unkelbach. Direct Leaf Trajectory Optimization for Volumetric Modulated Arc Therapy with Sliding Window Delivery. Med. Phys. 2013;40(6):388

29. J. Unkelbach, F. Dittmann, B. Menze, E. Konukoglu, and H. Shih. Evaluation of the Fisher-Kolmogorov glioma growth model for radiotherapy target delineation. Med. Phys. 2013;40(6):317

30. J. Unkelbach, C. Zeng, and M. Engelsman. The emergence of non-uniform spatio-temporal fractionation schemes within the standard BED model, Med. Phys. 2013;40(6):551 (Best in Physics distinction)

31. D. Giantsoudi, J. Unkelbach, D. Craft, C. Zeng, A. Trofimov, H. Paganetti. Radiobiological Implications of Various Target and Beam Geometry Utilization in Treatment Planning for Intensity Modulated Proton Therapy. Med. Phys. 2013;40(6):529

32. W. Chen, D. Craft, J. Unkelbach, T. Bortfeld. Near-global Beam Angle Optimization for Intensity Modulated Proton Therapy. Med. Phys. 2013;40(6):530

33. E. Salari, J .Unkelbach. Multi‐Criteria Direct Aperture Optimization. Med. Phys. 2013;40(6):356-357

34. D. Papp, J. Unkelbach. A Combinatorial Optimization Approach to Treatment Planning with Non-Uniform Fractions in Intensity Modulated Proton Therapy. Med. Phys. 2014;41(6):354

35. L. Dong, X. Zhu, J. Unkelbach, R. Schulte. The Status of Intensity Modulated Proton and Ion Therapy. Med. Phys. 2014;41(6):536

36. D. Craft, R. Bokrantz, D. Papp, J. Unkelbach. Sliding Window Multi-Criteria IMRT Optimization. Med. Phys. 2014;41(6):336

37. J .Unkelbach, D. Craft, T. Hong, D. Papp, J. Ramakrishnan, E. Salari, J. Wolfgang, T. Bortfeld. Exploiting Tumor Shrinkage in Split-Course Radiotherapy. Med. Phys. 2014;41(6):569

Narrative Report

My field of research is radiotherapy. Radiotherapy is one of the three main treatment options for cancer patients, besides surgery and chemotherapy. Today, approximately 50% of cancer patients receive radiotherapy during their course of treatment. Radiotherapy aims at irradiating the tumor with a high dose of ionizing radiation to achieve cancer cure. At the same time, radiation to healthy tissues surrounding the tumor is to be minimized to avoid side effects. As a physicist, I work on improving the precision and effectiveness of radiotherapy. My research focuses on improvements to the treatment planning process.

Radiotherapy treatment planning can be thought of as three problems:

1. Target delineation. Based on advanced imaging techniques such as computed tomography (CT) and magnetic resonance imaging (MRI), the tumor location and the volume that has to be irradiated needs to be identified.
2. Technology development. The technology to guide radiation precisely to the tumor, while avoiding healthy radiosensitive organs, needs to be developed. This includes the development of treatment planning systems, i.e. computer software to plan radiation treatments for each individual patient.
3. Temporal effects. The delivery of radiation has to be optimized over time in order to adapt to changes of the patient over the course of treatment, and to exploit radiobiological properties of tumors and healthy tissues.

My research activity reflects these three areas. Throughout my career, I have been working on the improvement of radiotherapy treatment planning systems, in particular the development of Intensity-modulated Radiation Therapy with high energy X-rays (IMRT) and Protons (IMPT). Nowadays, this area of research has a strong translational aspect: Through collaboration with industry partners (Philips Medical Systems), research results are integrated into commercial treatment planning systems and are made available for clinical use. In addition, the work is integrated into the in-house proton planning system that is used and developed at Massachusetts General Hospital. Over the years, I have been working on a variety of topics on treatment plan optimization including direct aperture optimization (DAO), rotation therapy planning (VMAT), multi-criteria planning, and robust planning (see publications

[16, 17, 21, 22, 38]).

The main contribution to the field during the initial years of my career relates to the handling of uncertainties in treatment planning (see publications [3, 5, 6, 10, 11, 12]). During therapy, numerous errors may occur: Such errors include incorrect positioning of the patient during irradiation, organ movements, and an incorrect patient model due to imaging artifacts. Such errors may severely degrade the quality of radiotherapy treatment plans, especially in proton radiotherapy. My research aims at improving error handling in radiotherapy by directly incorporating uncertainty into the optimization of IMRT and IMPT treatment plans. This can be achieved via robust und stochastic programming techniques. In collaboration with industry partners, this research is now implemented into the first commercial treatment planning systems.

Over the past 5 years, I have broadened my field of research towards target delineation and adaptive radiotherapy. Research in medical physics has refined the technical precision of treatment planning and delivery to a high level of sophistication. However, quantitative methods to determine the biological target volume and optimal dose distribution often lag behind. Improvements to tumor delineation require an interdisciplinary approach that involves imaging, statistical analysis of clinical data, and mathematical modeling. In particular, the integration of advanced imaging modalities in radiotherapy treatment planning bears potential. This includes positron emission tomography (PET) to measure the metabolic activity of tumors, as well as advanced magnetic resonance imaging (MRI) to measure physiological properties of tumors, such as blood perfusion.

Such an interdisciplinary approach is currently pursued for a project on tumor growth modeling for gliomas, the most common primary brain tumor (see publications [19, 20, 31, 32, 33]). Gliomas are known to infiltrate the brain parenchyma far beyond the tumor mass visible on current imaging modalities, which represents a challenge for radiotherapy planning. Phenomenological tumor growth models can be used to assess the microscopic infiltrative spread of tumor cells while accounting for the observed anisotropic growth patterns of these tumors. Medical image processing methods are used to personalize the tumor growth model to the brain anatomy of the patient at hand.

My third area of research is the optimization of radiotherapy treatments over time. Most treatments are fractionated, that is, the total radiation dose is split into small fractions, which are delivered over a period of 6 weeks. Over the course of treatment, a variety of changes occur, such as regeneration of healthy tissues and shrinkage of the tumor. Outcomes in radiotherapy can potentially be improved by optimizing treatment delivery over time. Recent works investigate this problem for a variety of applications including tumor shrinkage (publication [23]), scheduling of radiotherapy and chemotherapy (publication [25]), and the interdependence of fractionation and the spatial dose distribution (publications [15, 18]).