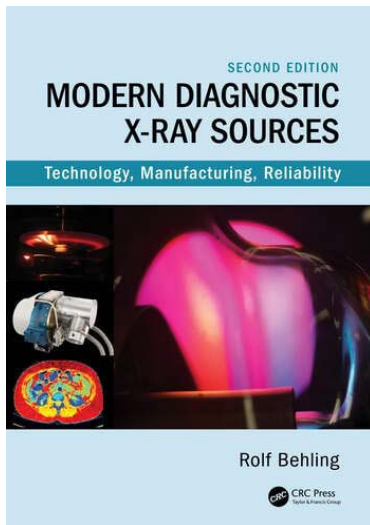


## **“MODERN DIAGNOSTIC X-RAY SOURCES – Technology, Manufacturing, Reliability” by ROLF BEHLING**

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**Abstract—** This article is a brief review of the textbook “Modern Diagnostic X-Ray Sources – Technology, Manufacturing, Reliability” by Rolf Behling (1<sup>st</sup> Edition in 2016 and 2<sup>nd</sup> Edition in 2021), CRC Press, Boca Raton, USA, ISBN-13 9781482241327 and 9780367546922



The book “Modern Diagnostic X-Ray Sources – Technology, Manufacturing, Reliability” is an unique publication covering specifically X-ray tubes used in contemporary medical diagnostic X-ray equipment. Its 2<sup>nd</sup> Edition was published in 2021 - ISBN 9780367546922. The 2<sup>nd</sup> Edition has more colour illustrations and extended focus on education (which is also very good in the 1<sup>st</sup> Edition).

The author Dr Rolf Behling is one of the top world experts in the field with some 40 years experience on the subject, including Head of the Philips Group for Advanced Development of X-ray Tubes and X-ray Generators. He is also part-time lecturer at the University of Hamburg, and after his retirement, is consultant in XtraininX, Germany.

Dr Behling is known to the readers of the Journal Medical Physics International (MPI) through his paper “Performance and Pitfalls of Diagnostic X-Ray Sources: An Overview” (MPI 2016, vol.4, No.2), and his history article “X-Ray Tubes Development” (MPI 2018, Special Issue 1).

The book has c.400 pages (additional to the 24 pages preliminary info, including 6 pages detailed content of the 10 chapters – see Amazon *lookinside*). The book includes c. 400 diagrams, figures and tables, supporting its educational value. The comprehensive book Index is on 15 pages.

The 1<sup>st</sup> Chapter “Historical Introduction and Survey” gives a comprehensive introduction of X-ray tubes development from Roentgen’s time, through various major steps of X-ray tubes design and development, including the first Rotating anode X-ray tubes, the Metal-Ceramic X-ray tubes, the Rotating frame X-ray tubes, various High-power CT X-ray tubes, etc. The chapter includes photos of the main types of X-ray tubes and discusses their principles.

The 2<sup>nd</sup> Chapter “Physics of Generation of Bremsstrahlung” present all necessary theory on the subject and links very well the theory with the generation of X-rays in diagnostic X-ray sources, formation of spectra, angular distribution of the Continuum radiation and Scattered radiation; Electron scatter in the anode and backscatter; Isotropic X-ray intensity distribution and the Heel effect.

The 3<sup>rd</sup> Chapter “Interaction of X-rays with Matter” looks as a standard chapter of this type, but again it includes various information and diagrams, related to absorption and scattering, rarely seen in the well-known textbooks on the subject. As in all chapters, here are listed main textbooks, which could be consulted.

The 4<sup>th</sup> Chapter “More Background on Medical Imaging” discusses the formation of the X-ray image. Comprehensively are covered the Linear Systems Theory and Modulation Transfer Function. The are also presented the foundations of Spectral imaging, Phase-Contrast imaging, Fluorescence imaging and Polarized X-rays.

The 5<sup>th</sup> Chapter “Imaging Modalities and Challenges” presents the foundations of Computed Tomography (with its sub-methods), Cardio and Vascular Imaging, as well as specific Radiographic equipment for Mammography, Dental and other applications. The types of X-ray tubes for these imaging modalities are specially discussed.

All these chapters are superbly presented as an unique mix of physical principles, engineering methods (see Fig.1)

and application procedures. This way of presentation is not seen in most of the existing books on the subject. The next 6<sup>th</sup> Chapter “Diagnostic X-ray Sources from the Inside” is almost a small book by itself. No similar chapter exists in all medical physics books. Here the industrial experience of the author shows the components of the X-ray tubes in a way which really opens the “black box” of the X-ray tube and presents the details of such a complex part of the equipment from the perspective of its engineering. The chapter is supported with many photos, diagrams and tables, which can be very useful both in the process of learning/teaching about X-ray tubes and in the process of selecting/purchase of such. The X-ray tube components: Anode, Cathode and others (rotor systems, drives, vacuum bearing) are given in an unprecedented detail. The chapter also discussed the ways of maintaining the X-ray tube vacuum. The chapter explains very well the subject and could satisfy even the most demanding lecturer or most curious student. This chapter can be seen as an example of presenting topics of applied physics – from the principles to their engineering application.

The 7<sup>th</sup> Chapter “Housings, System Interfacing and Auxiliary Equipment” covers the X-ray tube assembly, the shielding, filtration, beam limitation, cooling, protection of implosion and explosion, etc.

The 8<sup>th</sup> Chapter “The Source of Power” gives a comprehensive coverage of the main types of X-ray Generators and its components (transformers, rectifiers, stabilizers, wave forms, etc). The chapter includes block diagrams and electrical circuits.

The 9<sup>th</sup> Chapter “Manufacturing, Service and Tube Replacement” gives sufficient information for the medical physicist about these important engineering procedures. Average lifetime of X-ray tubes and main sources of failure are presented, together with associated warranty, Costs of ownership and recycling.

The 10<sup>th</sup> Chapter “X-ray Source Development for Medical Imaging” discusses the newest developments and trends in the field, such as Liquid metal anodes, Carbon nanotube filed emission cathodes, Non-bremsstrahlung sources of X-rays, etc.

The book is written very well – with logical and condense structure, which supports well its understanding. Reading the book requires knowledge of medical physics principles and is one of the best sources of information for preparation of lectures in the field of Physics and Equipment of X-ray Diagnostic Radiology.

The book of Dr Rolf Behling about X-ray tubes can be seen as a must for each Medical Physics Department with activities in X-ray Diagnostic Radiology – from Quality Control to selection/purchase of new X-ray equipment (and replacement X-ray tubes). For some countries the book can be seen also as a bridge between medical physics and clinical engineering activities.

We would like to conclude this brief review with a congratulation to the author for this unique excellent book with much needed detail about X-ray tubes – the devices which triggered the beginning of medical physics profession and still support over 2/3 of all medical imaging procedures.

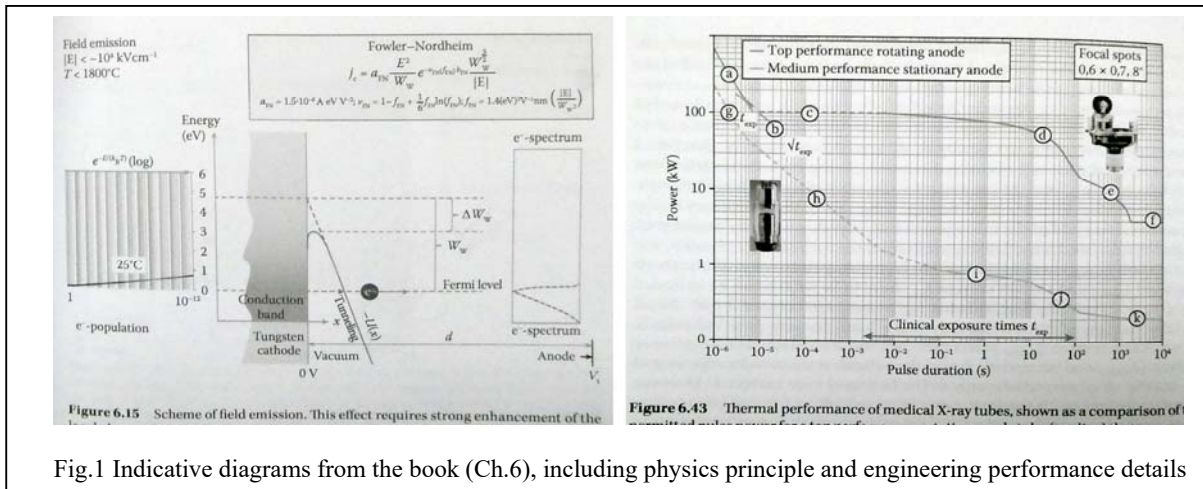


Fig.1 Indicative diagrams from the book (Ch.6), including physics principle and engineering performance details