Theoretical challenges by experimental physics: radiation and its interaction with matter

This computer presentation was designed to accompany the lecture. It does not include the whole content of the lecture, and thus should better be used with the recording of the talk.

Shaul Katzir, MPIWG

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Quantum mechanics as a result of the rise of theoretical physics:

Jungnickel and McCormmach:

Theoretical physics experienced some of its greatest advances, and German theoretical physicists played a significant and often leading part in [relativity theory and the early quantum theory]
• Seth: Theoretical physics, more general than microphysics, relativity and quantum theory
• Indeed; but also theoretical physics did not cover all theorization in these fields
• More traditional experimental physics also contributed to the quantum theory
• Theoretical physics for the introduction quantum hypothesis in heat radiation
  – with experimental data

• Experimental physics problematized theories of interactions between x-rays and light with matter
• Combination of evidence showed a need to introduce quantum assumptions
Experimental & theoretical physics

- Effects & relations
- Direct examination of hypothesis
- Theorizing by experimentation
- “experimental physicists”

- Testing of mathematical rules
- Theorizing separating from exp.
- “measurement physics”
The nature of x and \( \gamma \) rays

- A kind of EM waves on qualitative exp. results
  - Röntgen an “experimental physicist”
- Impulse hypothesis: theoretical idea on qualitative properties of the rays (strong & short)
- Paradoxes of quantity and quality
paradoxes of quantity and quality

- Quality: How the wave communicates such a high energy to the electrons?
- Quantity: Why so few ionizations?
- Exposed by studying properties, not by deviations from a rule
paradoxes of quantity and quality

• Quality: How the wave communicates such a high energy to the electrons?
• Quantity: Why so few ionizations?
• Exposed by studying properties, not by deviations from a rule
• Bragg’s solution - natural pair
Lenard (1902) “electron velocity is independent of the light intensity.”
• Explanation - The triggering hypothesis
  – Resonance used in other case, i.e. dispersion
• Extension to x and γ rays, supported by experimentally examining implications
  – E.g. electron velocity independent of intensity (Innes, 1907)
  – An answer for the paradoxes of quality and quantity
Testing the triggering explanation

• By experimental not measuring physics
• E. Ladenburg: independence of photo effect from temperature (1907)
  – Lienhop regarded that as support in 1905
Testing the triggering explanation

• Continuous velocity spectrum
• Only after these, relation between velocity and frequency
  – Indecisive results exemplify the limitation of the measuring approach
• Decisive results only in 1916 - Millikan
• Yet, was not regarded as a confirmation of Einstein’s theory, only if his equation
Testing the triggering explanation

- 1911, Lenard and Ramsauer, direct implication: correlation between energy of light and electron
- Contradicting any triggering mechanism, highlighting the paradoxes
- Consequently most rejected triggering mechanism
Light and x-rays

• Separating x-rays from light - reduces its contradicting properties
  – Enabled W.H.Bragg’s and Thomson’s

• However, support for the similarity, by experiments designed to examine particular parallels, not derivations from elaborated theories
1907, x-rays velocity independent of intensity
-Ultraviolet emits more electrons in the direction of light (1910)

Stuhlman (1910)
Light and x-rays

- X-ray diffraction (Laue et al. and the Braggs), only added to the conviction
  - Meaning of results by theory (of the Braggs), but still general behaviour, not an exact math. rule
The view of x-rays as light

• Qualitative argument against energy source in the atom
• “Estimated” argument for Einstein’s relation

Pohl and Pringsheim (1913):

‘extrapolation to the probable frequencies of the Röntgen spectrum leads to velocities for the electron liberated by Röntgen rays which agree in order of magnitude with those experimentally observed.’
Post 1910 theoretical accounts

- Regaining Einstein’s equation
- Thomson’s atomic model (triggering)
- Planck, Sommerfeld & Debye using quantum conditions, not light quantum
  - Quantum hypothesis connected to other fields
  - Marx showed short delay, 1913
  - Contradicting an implication of Sommerfeld et al.
Post 1910 theoretical accounts

• Richardson’s descriptive theory
• No popularity - physicists were not satisfying in bypassing the challenges
• Rejection of light quanta
Millikan:

The new facts in the field of radiation . . . seem, then, to require in any case a very fundamental revision or extension of classical theories of absorption and emission of radiant energy.

- Facts from x and γ rays ionization, photoelectricity, and black-body

- Most originated in “experimental physics”