Heisenberg's quantum mechanics and wave-particle duality.

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Hundred years ago Werner Heisenberg published the very first paper of modern quantum theory [1], formulating the basics of matrix mechanics [2]. In the present contribution we attempt to follow the development of quantum theory around the time of this discovery, and also show some direct connections to attosecond physics, like the non-linear oscillator problem discussed in [1,2], or the Kramers-Heisenberg dispersion formula. We shall also deal with the Heisenberg uncertainty relation [3–7], which came out from an analysis of physical observations, by using Born's probability interpretation [4]. In this context the significance of the proper definition of the degrees of freedom of the radiation field and the physical structure of the (quantum) phase space will also be discussed. The so-called Drei Maenner Arbeit (three men's work) of Born, Heisenberg and Jordan [2], submitted also in the year 1925, will also be highlighted.

This work also contains a first version of field quantization, namely, the quantization of the normal modes of an oscillating string. As an application of this new formalism, the authors derived [2] an analogue of Einstein's fluctuation formula (1909) expressing the wave-paritcle duality of black-body radiation [9]. According to this result, both the wave-like and the particle-like fluctuations are simultaneously showing up, which is important *e.g.* in quantifying the noise-performance of detectors, or in the photon correlation experiments. We plan to give a brief comparison of wave mechanics and matrix mechanics in two examples: the oscillator coherent packets derived by Schrödinger [8], and the squeezed state amplitudes (which appear *e.g.* in parametric amplification) constructed by Kennard [5], who used the transformation theory of Jordan [6] and Dirac [7].

References

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