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Monochromatizing without filtering using dynamic fields without bunching: A new concept for d-TEM illumination

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Commonly used monochromators are energy filters. The majority of the particles with undesired energies is removed. Thus the output current diminishes with increasing degree of monochromatization.

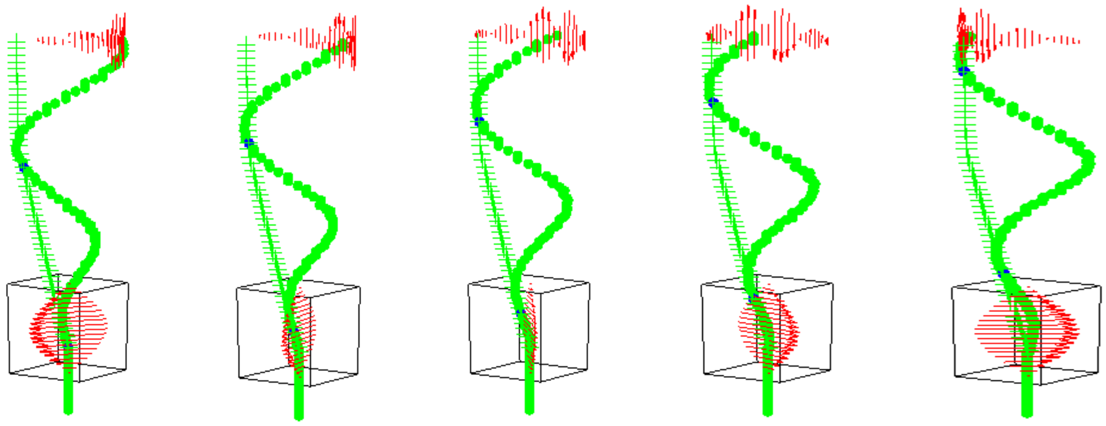
Monochromators in the original meaning of the word that would affect the energy of the particles by an energy selective acceleration can only be realized by use of dynamic fields.

Dynamic field applications without exception involve a condition between the phase of the dynamic field and the entrance point of time of the particle into the field. If this condition is fulfilled, the dynamic field application works exactly. Unfortunately the width of the time interval where the condition is fulfilled is mathematically zero. Thus up to now dynamic field applications in charged particle optics limit themselves to a small time interval around the periodically recurring point of optimum phase where the condition is fulfilled to a good approximation. For that purpose bunches are formed around the optimum phase point. Unfortunately bunch forming suffers from Liouville's theorem: The product of the bunch length and the energy spread within it is a constant.

In this work a concept is presented that circumvents this dilemma. A circularly polarized standing wave deflects the charged particle beam to a rotating orbital feeding the particles into a propagating wave that rotates within a toroidal wave guide (see figure 1.). The circular deflection supplies a time coding. The entrance point of time of any particle is locked to its azimuthal position. Provided that the deflecting field and the rotating propagating wave (denoted by working field in the following) are synchronized correctly the optimum phase condition is fulfilled exactly and constantly. Time uncertainty vanishes within the limits of technical & practical implementing of the concept. The working field may be cascaded. It can be used for a large variety of applications such as monochromatizing, accelerating, pulse forming, spread amplification, spread inversion, time focusing and aberration correction (only examples for monochromatizing and time focusing applications will be given in this contribution). In the end the spiral orbital may be focused to an inverse circular deflector that undoes the action of the first circular deflector and thus leads the particles back to the original axis (see figure 2.).

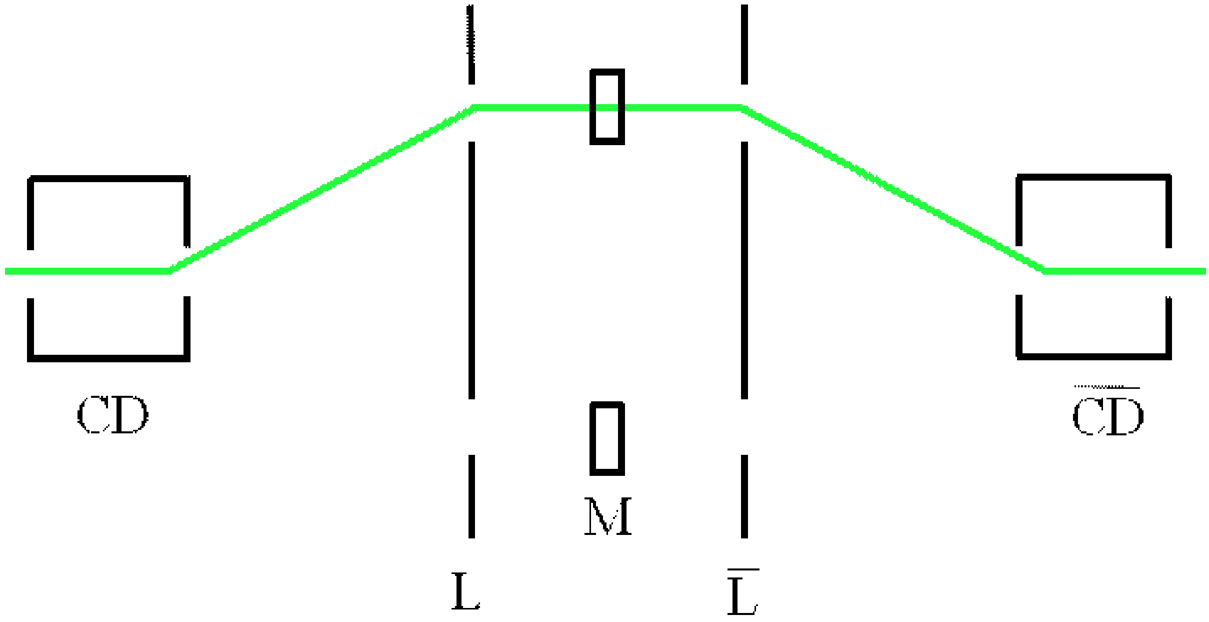
Computer simulations assuming theoretically ideal TE10 mode microwaves as dynamic fields showed that the dispersion of circular deflection can arbitrarily be chosen. Furthermore a monochromator based on circular deflection was demonstrated to work by computer simulation. The energy spread vanishes within the limits of technical & practical implementing of the concept without any loss of current.

Finally, a vision of a dynamic TEM illumination column based on circular deflection yielding equidistant monochromatic single-electron pulses will be presented. The latter concept makes use of plasmonic field emitters synchronized to the deflection and working fields.



5 snapshots of animation showing circular deflection; Roland Janzen

Figure 1. Five snapshots of an animated schematic drawing illustrating the principle of a typical circular deflection application. The circular deflector wave is a circularly polarized standing wave within a cubic resonator. The electric field vector (shown by the lower group of red arrows) rotates, always pointing perpendicularly to the direction of motion (which is in this figure assumed to point upwards) of the electrons (green). The working field is represented by the upper group of red arrows. It is a propagating wave that is rotating within a toroidal resonator (not shown). If both waves are synchronized properly all electrons arrive at the working field at optimum phase. The electron marked in blue and the corresponding trajectory marked by crosses show that the deflected electrons do not have any azimuthal velocity though their orbital performs a spiral rotation.



Scheme of circular deflection based monochromator, Roland Janzen

Figure 2. Schematic drawing (cross sectional view) of a simplified monochromator design based on circular deflection. Note that in difference to figure 1 the electrons are assumed to move from left to right. They are deflected by the circular deflector CD, focused by some lens like element L, monochromatized by the working field inside the toroidal resonator M, focused again and deflected by an ‘undoing’ circular deflector in the end. In order to emphasize the symmetry of the design we used the complex conjugate notation for the names of the elements at the right hand side of the monochromating wave