MONOCHROMATIZING WITHOUT FILTERING: PROPOSAL FOR A MICROWAVE BASED LOW LOSS MONOCHROMATOR FOR S(T)EM

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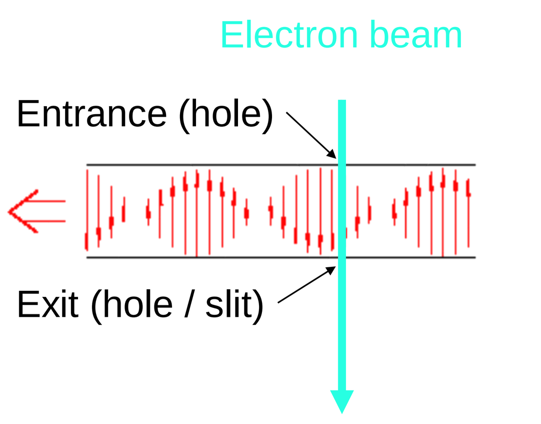
Motivation

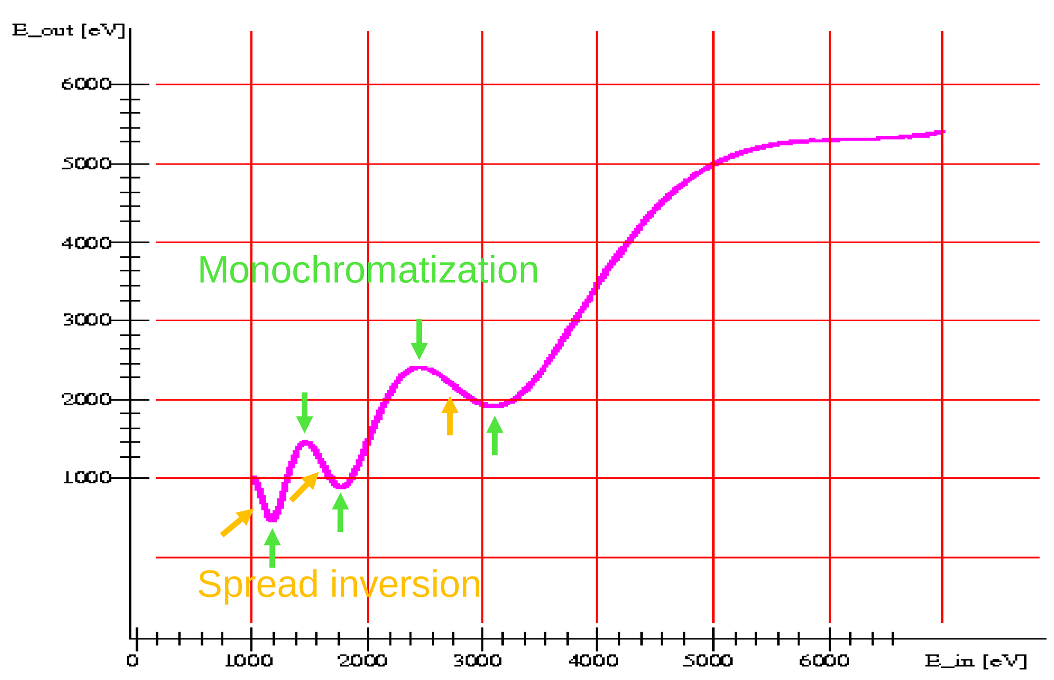
- Commonly used monochromators are energy filters.
- The output current diminishes with increasing degree of monochromatization.
- Desirable: Reducing the energy spread (at full current) by an energy selective acceleration.
- Dynamic fields can do that.

Principle

- Let's study electrons entering a TE-10 mode propagating microwave within a rectangular wave guide with following subconditions:
  - Direction of electric field vector is parallel / antiparallel to direction of motion of the electrons
  - Entrance at fixed point of time (i. e. fixed phase)
  - Mean energy of the electrons is such that they spend several periods of oscillation within the wave guide



Schematic sketch of an interaction study (by computer simulation): Electrons are travelling through a (propagating) longitudinally oscillating wave.



Result of an interaction study: Energy E_out at the exit as a function of the energy E_in at the entrance

Result: Phase locked entrance condition provided, dynamic fields can serve as:

- monochromators,
- Spread inverters,
- Spread amplifiers.

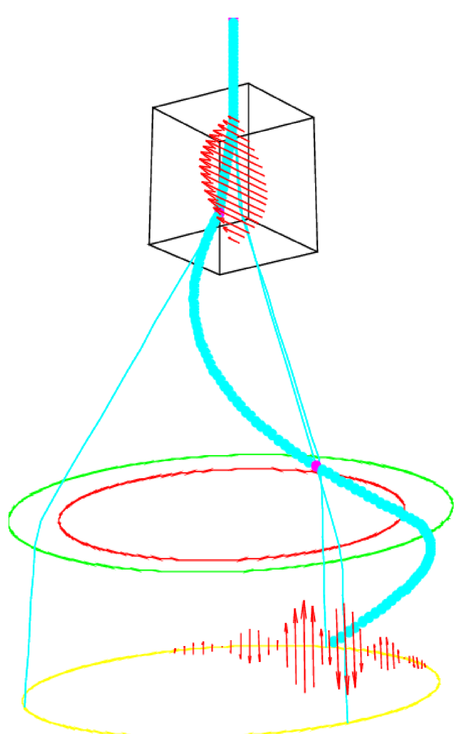
Mode of operation is defined by the mean energy of the electrons and the amplitude of the field.

Note: Monochromatization does not violate Liouville's theorem: The energy spread is transferred to the wave which is acting as a thermal reservoir.

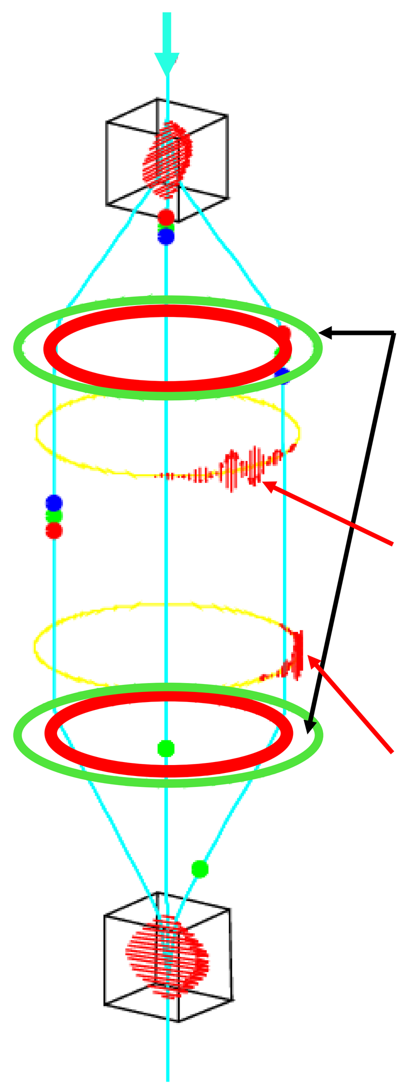
Circular deflection

How to realize the phase locked entrance condition?

- Combine a (perpendicularly oscillating) circularly polarized deflection field with a
- propagating (longitudinally oscillating) wave orbiting in a toroidal wave guide (not shown)



The circular deflection based monochromator



circular deflector links entrance time of electron with its azimuthal path position

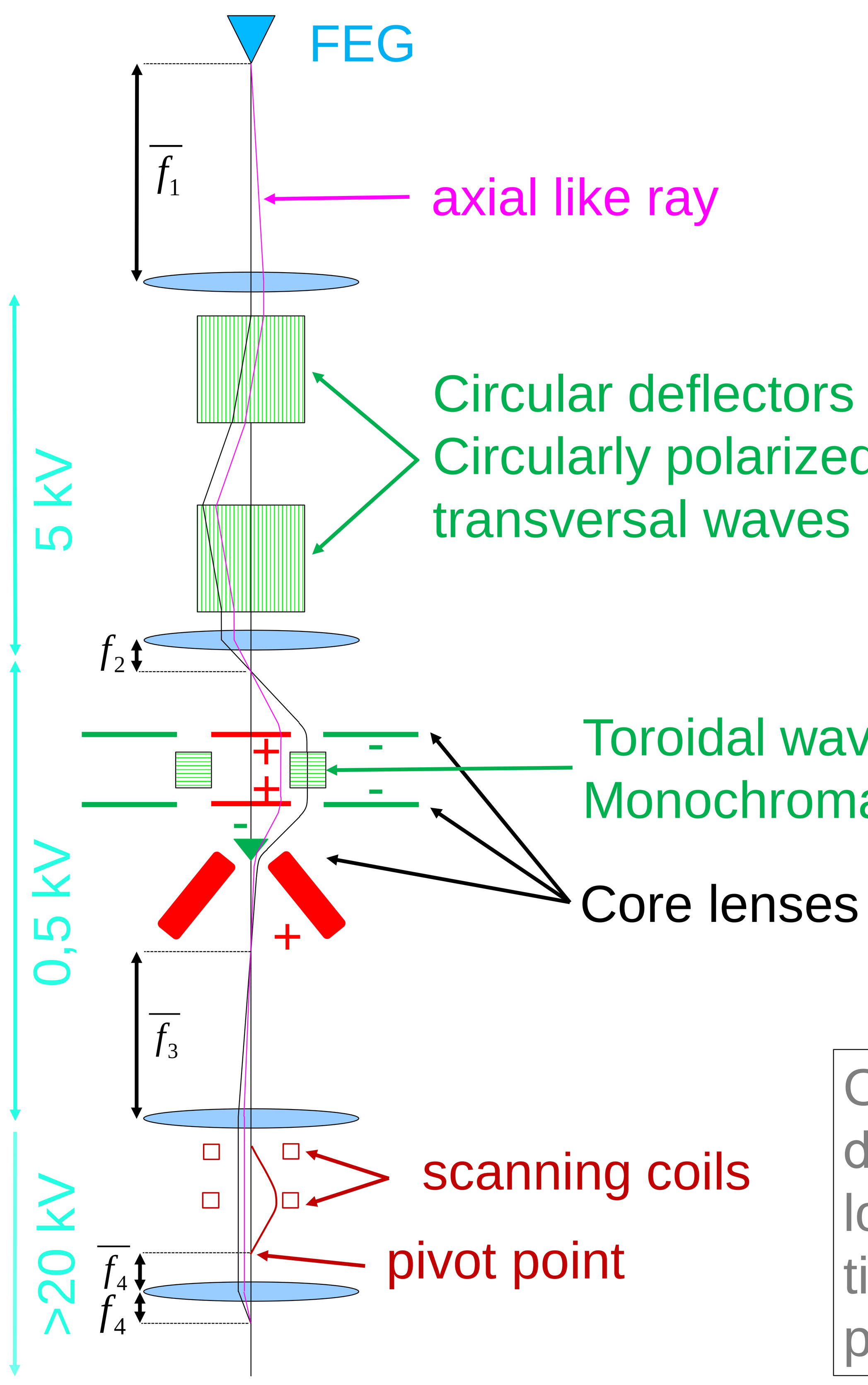
focussing elements transform hollow cone beam to barrel beam and back

orbiting wave performs inversion of energy spread in order to cancel out time of flight dispersion

monochromatizing wave (on its orbit (yellow))

Cleaning up: Second circular deflector undoes the deflection → electrons are back on axis after monochromatization

Approach for S(T)EM



Omitting the 'undo deflector' yields hollow cone illumination in the scanning probe.

Summary

Circular deflection opens the door to dynamic field applications without bunching.

Within the limits of some simplifications (neglect of magnetic fields, width and angular spread of beam) monochromatizing at nearly full current is theoretically feasible.