Thesis subject

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Subject's title:

Hamiltonian Description of the Electrodynamics, via the Poisson Algebra of Maxwell-Vlasov. Application to the Physics of Magnetically Confined Plasmas.

Subject description: This PhD thesis will study a geometrization of the Hamiltonian approach of classical electrodynamics, via (non-canonical) Poisson structures. This relativistic Hamiltonian framework (introduced by Morrison, Marsden, Weinstein) is written in terms of differential forms, independent of the gauge potentials, and is well suited for a perturbation theory, in a strong inhomogeneous magnetic field (expansion in $1/|B|$, with all the curvature terms...).

This algebraic and geometric description of the Vlasov kinetics yields some very concrete applications.

The work will focus in particular on the explicitation of the reduced dynamics of the "gyro-center", by lifting and perturbing the reduced "guiding-center" dynamics, in order to improve the efficiency of the computation and the confinement of the magnetically confined plasmas. For instance in view of the thermonuclear fusion, as in Tokamaks (international project ITER, in CEA-Cadarache) or Stellarators. The geometric approach may be implemented in any coordinates, for instance adapted to the Tokamak (toroidal coordinates or even more adapted...).

More precisely, this algebraic approach introduces a Poisson bracket which reproduces the Maxwell and Abraham-Lorentz equations. This is useful to describe some optimized coordinates ("normal form"), adapted to the non-trivial constants of motions ("actions"), when the magnetic field is strong. The numerical integration in these coordinates is simplified since its spatial dimensionality is reduced from 6 to 4.

Another application is the generation of higher harmonics in "Free Electron Lasers" (FEL), to create Lasers with high frequencies (toward X-rays), by interaction of ultra-relativistic electrons in a strong inhomogeneous magnetic field.

A possible extension of this work is the quantization "by deformation" of this Poisson algebra, to get a Quantum Electrodynamics, independent of the gauge potentials, via a Lie-Jordan structure.

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