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A3_5: Possibility of Creating a 'Star Wars' Lightsaber

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Abstract
This papers examines whether or not a 'lightsaber' weapon can possibly be produced and used in the same manner as in the 'Star Wars' film series. It will examine whether the title 'lightsaber' is indeed misleading in terms of describing a mechanism by which such a weapon could possibly be made. The paper considers elements of plasma physics to reach a conclusion, and it turns out that the lightsaber cannot be made (at least with today's technology) akin to that shown in the well-known 'Star Wars' movies.

Introduction

For those unfamiliar with the lightsaber weapon as depicted in the *Star Wars* film series, is it a weapon that resembles a sword whose blade resembles a [1]luminous beam. It can cause precise, intense burning of an object upon which it impacts, akin to that of a very powerful laser.[1] [2]The word 'lightsaber' is misleading because the Pauli Exclusion Principle implies that any number of bosons (including photons of light) can occupy the same quantum state,[2] meaning that during a lightsaber duel, one could not deflect a striking blow from the opponent's blade. So, to produce such a weapon, a mechanism is needed that is not based around photons of light, but is still luminous. A way of doing this would be to have a blade made up of plasma, similar to that shown in *figure 1.*

Theory

In order to make the blade with the required properties, that can cut most materials, a plasma of temperature of at least [3]4000K to be confined somehow, is needed.[4] Mechanisms for plasma confinement include gravitational, magnetic and inertial confinement. Gravitational and inertial confinements are not feasible as the densities of particles required is too great.[4] Therefore, one shall now investigate the possibility of using a magnetic confinement mechanism, as shown in *figure 1.*

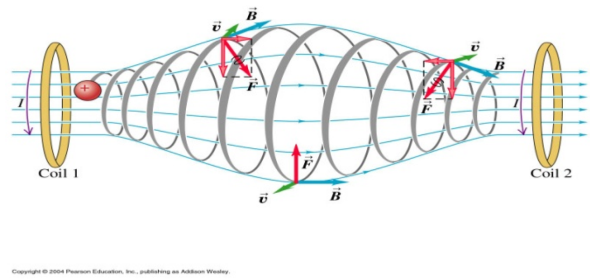

Figure 1: [5,6]A magnetic bottle can be used to magnetically confine plasma. Charged particles near either end of the current coils (carrying current, I) experience a magnetic force directed towards the centre of the region of the 'bottle' shaped magnetic field.[5,6]

This above method can contain very hot plasmas with temperatures ~10^6K. A realistic 'lightsaber' would require these current rings at both the hilt and tip of the blade.

The magnetic force ***F,*** on a charged particle with charge *q,* and velocity ***v,*** in magnetic field ***B,*** is given by:

$$\mathbf{F} = q\mathbf{v} \times \mathbf{B}. \quad [1]$$

The minimum energy of a charged particle in plasma is ~ *kT,* where *k* is the Boltzmann constant, and *T* is the temperature of the plasma. Equating *kT* to the kinetic energy of a charged particle of mass *m,* gives:

$$kT = (1/2)\, m\mathbf{v}.\mathbf{v} = (1/2)mv^2. \quad [2]$$

[7]In a static B field (including that of the magnetic bottle) it is known that:

$$v_{perpendicular}^{2} + v_{parallel}^{2} = constant \text{ [3]}$$

[7]where $v_{perpendicular}$ and $v_{parallel}$ are respectively the velocities of particles perpendicular and parallel to the field lines in the magnetic bottle. It can be shown in any standard text on plasma physics for two different magnetic fields under consideration B_1 and B_2,

$$(\sin^2 \alpha_1)/B_2 = (\sin^2 \alpha_2)/B_1, \text{ [4]}$$

[7]where α_1 and α_2 are their corresponding *pitch angles*[7] [8] which is the angle between the particle's net velocity and the magnetic field at a given point.[8]

[8]For $\alpha_1 = \alpha_0 = 90^o$, $B_1 = B_0$ = the minimum field strength, and $B_2 = B_m$, known as the mirror field, such that the particles are reflected from one of the magnetic mirrors shown in *figure 1* towards the other. [8]Therefore one has: $\sin^2 \alpha_0 = B_0/B_m$, from which when $B_m = B_{m\ max}$, and particles with: $\sin \alpha_0 < (B_0/B_m)^{1/2}$ are not reflected, and not contained within the magnetic bottle arrangement. [7]A particle only remains *trapped* in the magnetic bottle, if its pitch angle remains such that:

$$\arcsin (B_0/B_m)^{1/2} \leq \alpha_0 \leq 180^o - (\arcsin B_0/B_m)^{1/2}, \text{ [5]}$$

where B_m is the weaker of the magnetic fields. It can be seen from [5] that if B_0 (the field in the centre of the bottle as shown in *figure 1*), is kept comparatively smaller than B_m , then [5] is easily satisfied for many values of α_0. From this one sees that the magnetic bottle confinement method is feasible, one can progress to the argument that follows. Assume for simplicity that plasma contains only hydrogen ions, with no ions lost in the *loss cone* (a detailed discussion is beyond the scope of the paper and does not affect the conclusion of this paper). Assume that the mass of the particle is the average of that between the protons and electrons (because hot plasma which is being considered here is is completely ionised) and that T ~ 10^6K. Knowing these quantities and that q is the fundamental charge e, means that equation [2] yields v of the order: 10^5 ms^{-1}. Considering the situation at the hilt and tip of the blade, $\boldsymbol{v}$ is approximately perpendicular to $\boldsymbol{B}$, meaning that [1] gives an inward force containing the plasma ~10^{-14}N; tiny compared to the magnitude of forces exerted in typical sword fights, This means that during a duel, the blows sustained could cause high temperature plasma to fly out, so it would be highly dangerous to use one of these plasma swords.

Conclusion

It would be difficult to be able to make a lightsaber in the manner shown in the films. The intrinsic shape of a magnetic bottle as shown in *figure 1* means that the sabre would probably be more 'bottle' shaped than the slim, linear, homogenous blades as portrayed in the movies.

References

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