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## Should the laser weapons in *Fallout* have recoil?

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### Abstract

The post-apocalyptic world of the *Fallout* series features a wide variety of technologically advanced weaponry, including laser weapons. This paper aims to establish whether or not these weapons should recoil upon firing as they do in the game. This will be done via two methods, the first of which is based off in-game damage values and comparison to the real-life counterparts of the in-game ballistic weaponry. The other method is through the determination of the vaporisation energy of the largest creature it is capable of disintegrating. It was determined that the laser weapons should not have perceivable recoil based upon their in-game damage. However, when considering their ability to disintegrate targets, the recoil was calculated to be of such large magnitude that the weapons would be unusable.

### Introduction

*Fallout* is a series of role-playing video games, set in a post-apocalyptic, retro futuristic wasteland after total nuclear annihilation occurred in the year 2077. The 1950's post-war culture's hope for outlandish future technology, and the seeming inevitability of nuclear war define the world of *Fallout*. Among this advanced technology is an array of laser weaponry.

The laser weapons in the *Fallout* series have recoil similar to the conventional ballistic weaponry in the series. However, the photons fired by the laser weapons are not projectiles in the traditional sense; they have zero rest mass. However, they do carry a momentum, and can apply a radiation pressure to surfaces they make contact with [1]. This paper will investigate if the momentum change of the gun upon firing is sufficient to cause recoil of the magnitude seen in the games.

### Theory and calculations

The energy imparted to the light must be conserved, and so the laser weapon must recoil backwards with a momentum equal to that of the laser beam. The energy of light  $E$  is related to its momentum  $p$  by [1]:

$$p = \frac{E}{c}. \quad (1)$$



Figure 1 – Laser pistol recoiling as it is fired [2]

The base AER9 laser pistol in *Fallout 4* does half the damage of the base .44 pistol (a gun infamous for its strong recoil) [3, 4]. If this is considered analogous to the energy carried by each 'projectile', then the laser beam carries half of the energy of the .44 bullet, which is its kinetic energy:

$$p_{\text{Laser}} = \frac{\left(\frac{1}{4}mv^2\right)}{c}. \quad (2)$$

The .44 pistol has a muzzle velocity of  $434 \text{ ms}^{-1}$  and a bullet mass of 22 g [5]. This gives a ratio of their momentums as:

$$\begin{aligned} \frac{p_{\text{Laser}}}{p_{.44}} &= \frac{\left(\frac{1}{4}mv^2\right)/c}{mv} \\ &= \frac{3.4532 \times 10^{-6}}{9.548} \\ &= 3.617 \times 10^{-7}. \end{aligned} \quad (3)$$

The momentum experienced by the .44 pistol is roughly 2750000 times larger. Therefore, the recoil of the laser pistol should be negligible.

However, it could be the case that in-game damage is not representative of the energy imparted upon the target. The laser weapons of *Fallout* are capable of completely disintegrating enemies, reducing them to a pile of ash. We will assume that this process requires roughly the same energy as vaporisation. A previous JIST paper calculated the total amount of energy required to completely vaporise an adult person (78 kg) to be  $2.99 \times 10^6$  kJ [6]. However, the weapons are capable of vaporising much more substantial targets; the largest of which is arguably the Super Mutant Behemoth.

Super Mutants are created from humans that come into contact with Forced Evolutionary Virus (FEV), resulting in them becoming significantly larger and more muscular. The largest of the Super Mutants are the Behemoths, coming in at around 20 feet tall [7]. The mass of a Behemoth is not documented, but regular super mutants are known to stand approximately 7.8 feet tall and weigh around 800 pounds [8]. Scaling the mass of a standard super mutant up three dimensionally will give the mass of a behemoth:

$$\begin{aligned} m_{Behemoth} &= 800 \times \left(\frac{20}{7.8}\right)^3 \\ &= 13486 \text{ lbs} = 6117.1 \text{ kg}. \end{aligned} \quad (4)$$

This gives an energy of vaporisation of:

$$\begin{aligned} E_{Vaporisation} &= \left(\frac{6117.1}{78}\right) \times 2.99 \times 10^6 \\ &= 2.3449 \times 10^8 \text{ kJ}. \end{aligned} \quad (5)$$

Using equation (1) gives the momentum of the laser:

$$p_{Laser} = \frac{2.3449 \times 10^{11}}{3 \times 10^8} = 781.63 \text{ kg m s}^{-1}. \quad (6)$$

This gives a new ratio of momentums of:

$$\frac{p_{Laser}}{p_{.44}} = \frac{781.63}{9.548} = 81.863. \quad (7)$$

This indicates the laser pistol will experience a momentum roughly 82 times larger than the .44 pistol. Without some form of extremely effective recoil compensation, this level of recoil would render the laser pistol unusable as a handheld weapon, likely causing the user significant injury. Such a recoil compensation system is not currently possible, and there is no mention of such a system in the lore of the *Fallout* universe.

### Discussion

The energy output of the laser based upon its ability to disintegrate is approximately 234 million times greater than the energy determined from its in game damage value. This extremely large discrepancy indicates the ability of the laser weapons to disintegrate foes is very unrealistic considering their damage output relative to ballistic weaponry. It can take tens or even hundreds of shots from a laser pistol to take down a Behemoth, only for the last shot to vaporise the enormous creature entirely [7]. This is illogical given that if the laser was capable of causing vaporisation, it would occur on the first shot.

The developers have clearly given this subject some thought; shooting a clutter object such as a tin can with a ballistic weapon will send it flying, whereas a laser weapon does not move it at all. This shows they purposely made the momentum imparted by the laser be negligible, making their choice to implement non-negligible recoil to the weapons seem questionable.

### Conclusion

When considering the in-game damage value of the AER9 laser pistol from *Fallout 4*, the recoil is calculated to be  $3.6 \times 10^{-7}$  that of a .44 handgun. This extremely low level of recoil would be negligible. When considering the ability of the laser weapons to disintegrate even the largest enemies, the recoil is calculated to be 82 times that of a .44 handgun. This level of recoil would render the weapon essentially impossible to use. As the laser weapons in *Fallout* do not instantly kill, it can be assumed that the energy based on the damage is the 'true' value. Taking this to be the case we can conclude that the laser weapons in *Fallout* should not have perceivable recoil, and the capability of disintegrating enemies is unrealistic.

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