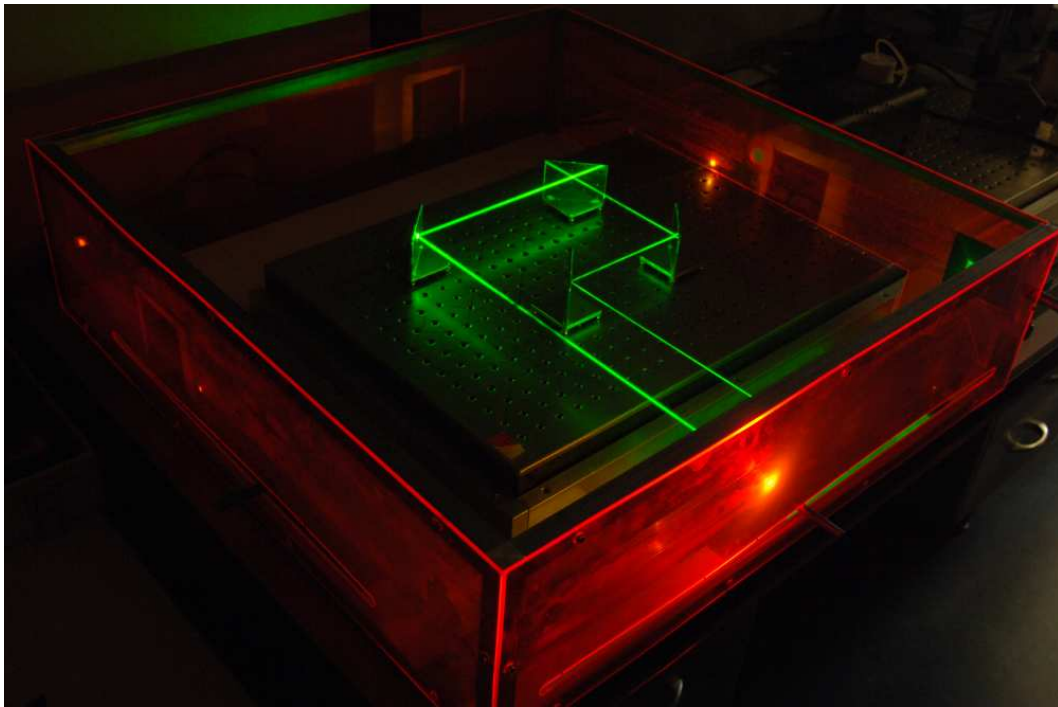


# Black Box - An implementation using Lasers, Smoke and Fluorescence

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## 1 Introduction

Black Box is a well known game, invented more than 30 years ago by Eric Solomon. It first was published by Waddington and later by Parker Brothers. The objective of the game is to find balls hidden in a regular grid (the “black box”) by the deflection of input balls shot into the black box. You might want to try out the game online, e.g. at <http://www.bieault.org/blackbox/>.

This sort of ball-deflection is similar to the deflection of light at mirrors. Therefore, we thought about an optical realization of the game with the aim to give an impressive display to people watching the game.

## 2 Optical realization

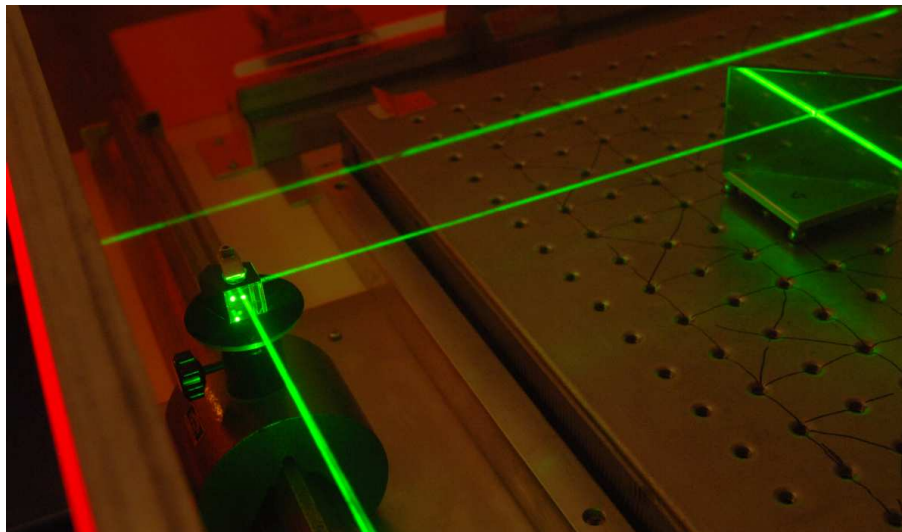
The basic idea, of course, is to use laser light directed to mirrors at angles of  $45^\circ$ . The basic system uses a

frequency-doubled Nd:YAG laser ( $\lambda = 532 \text{ nm}$ ,  $P \approx 10 \text{ mW}$ ) together with a cheap smoke generator (30 Euro at eBay).<sup>1</sup> The smoke is employed to make the laser beam visible on its way through the black box.

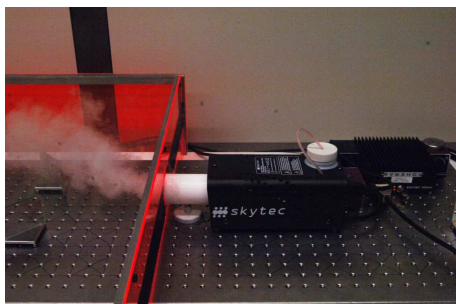
One main problem is how to make the beam visible to spectators watching the player while the player herself only should see a black box. To this end the player wears laser safety goggles, blocking all green light. The cover of the black box is assembled using green transparent plexiglas. Therefore, looking inside the box while wearing the goggles is not possible. Also, the green laser is, of course, not visible in this case for the player.

But given that, how should the player know where the laser exits the black box? Fluorescence comes to our help. The border of the black box is made out of orange fluorescent plexiglas. Therefore, the green laser hitting the border leads to the emission of or-

<sup>1</sup>More sophisticated smoke generation is necessary if one wants to avoid pollution of the optics.



(a) A penta prism is used for the  $90^\circ$  deflection (left side). Mirrors are glued on a aluminium sheet glued onto steel balls (right side).



(b) Smoke generator



(c) Laser safety goggles are used to hide the laser and its path from the player

Fig. 1: Some components

ange light which will be easily seen by the player wearing the goggles. Additionally, this orange plexiglas helps for achieving laser safety because large part of the green laser light is absorbed (and incoherently reemitted).

The basic deflection-by-mirror idea only works if the angles of all mirrors are more or less correct. Therefore we used optical rails on the two input sides and a movable penta prism (leading to exact  $90^\circ$  deflection) to couple the light into the box. The mirrors were glued (while used as deflectors) exactly on aluminium plates glued on steel balls. The steel balls fit nicely on the optical breadboard that we used as the base plate.

If you plan to build a similar device: Be careful with the laser safety. The impressive glow of the beam and the edges of the fluorescent plastic (total internal reflection), of course, need optical power. This means

that you have to use some milliwatts to have an impressive display. But this also means that you have to insure mechanically that no mirrors can fall down or tilt in an unexpected way.

### 3 Is it worth the whole work ?

Definitely, the optical black box game looks spectacular in a dark room and it is a nice eye catcher. If you have access to all the optical devices (laser, breadboard, mirrors) the realization is not so hard. The game itself is easily adapted to different levels of difficulty by using more or less mirrors inside the box. Therefore, small children as well as grown-ups might have their fun. On the other hand, the game is a little bit too long for occasions where people want to play only for about one or two minutes.

We want to thank Margarita Riedel for the nice photographs.