DVD-Drive-Based Laser Scanning Microscope

Due to an abundance of one specific type of DVD drives, plans were made to give a useful afterlife to these devices. A laser scanning microscope seemed to be the most useful project.

Preface

This project was inspired by the work done by Hannes Zöllner towards his Ph.D., during which he evaluated commercial DVD drives for fault injection in semiconductor devices. At some point, his system was also repurposed for imaging, with surprisingly remarkable results. An effort was made to optimize the system used in this project for imaging rather than for fault injection.

A DVD drive is a remarkable device, being able to discern the height of tiny pits of about 440 nm in length, laid out in tracks separated by only 780 nm. Of course, Blu-Ray technology decreased both these numbers further, but DVD drives tend to be thrown away in large quantities these days, which makes them available to the hobbyist basically free of charge.

Concept

The OPU (Optical Pickup Unit) of a DVD drive normally contains all the optical and most of the electrical components required to read data from a disk. Normally, it includes laser diodes (and sometimes their driver electronics), a multi-quadrant detector diode (PDIC or OPIC), the required optical elements (lenses, mirrors, prisms, gratings) and the actors for focus, tilt and tracking control (typically electromagnetic actuators moving the primary lens close to the disk). Normally, the OPU is mounted on a linear rail equipped with a stepper motor for one-axis position control.

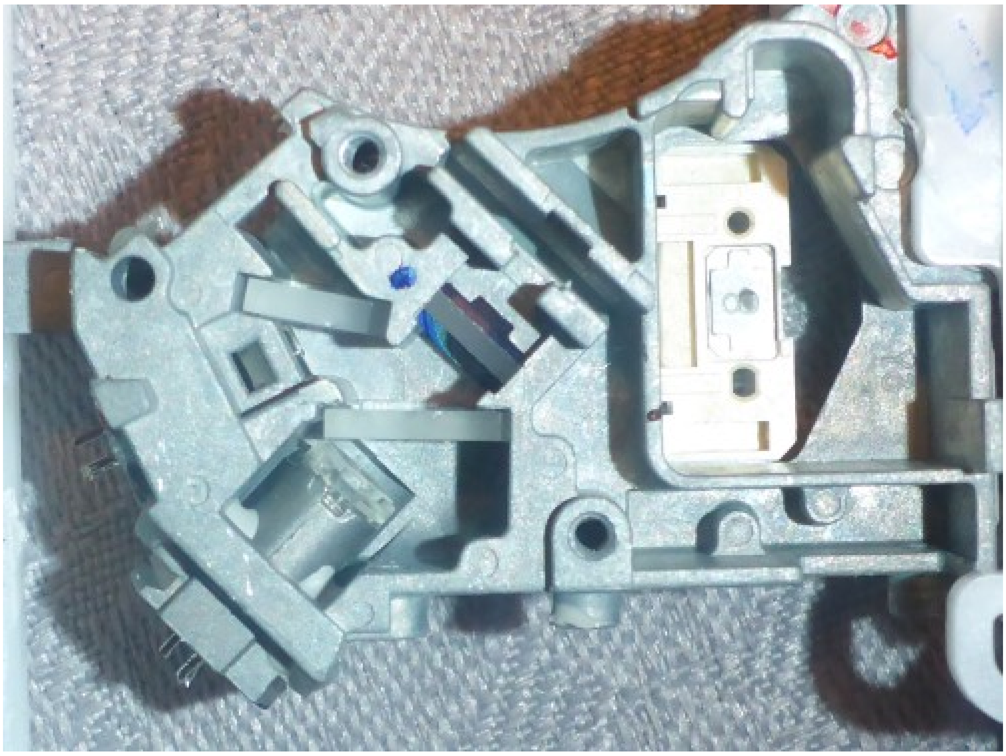
In the available drives, all OPU components are interfaced using a single FFC (flat cable) to a custom board that houses a proprietary microprocessor and various components not quite available to the average consumer. Therefore a replacement for these electronics that utilizes commercially available components open source hardware/software should be created.

This replacement should provide the following basic functionalities:

- Interface to PC for data acquisition
- Driving of OPU actuators (lens coils)
- Driving of laser diode(s)
- Readout of the PDIC for focusing and image acquisition

OPU Architecture

The OPU in the available drives is a tightly integrated component, mostly consisting of a single cast-aluminum block, in which various optical components are glued. A top-down-view of the OPU after removing the cover can be seen below.



Laser Diodes

The OPU houses two laser diodes. As this is just a DVD/CD reader, the lasers are not very powerful but provide sufficient power for microscopic applications. The (red) DVD diode starts laser operation above approx. 60 mA and requires about 2-2.5 V of forward voltage. Its polarity could be easily determined by measurements.

Lens Actuators

The primary lens is positioned using electromagnetic actuators. These come in the form of three coils, which tilt or move the coil proportionally to the current flowing though them. Their polarity and required full-scale DC current can be easily found by using a lab power supply.

PDIC

The PDIC (Photo Diode Integrated Circuit), in a DVD reader application, serves multiple purposes. These include gathering focus, tilt and tracking information from the disk as well as recovery of the RF data stored on the disk tracks. For this reason, PDICs typically consist of at least 6 active diode areas, sometimes even more. The PDIC used in the available drive type is seen below.

TODO Picture

Initial pinout probing revealed only the power supply pins and a number of analog output voltages, however no datasheet for a PDIC with matching pinout could be found online. To be able to re-use this component, a little reverse-engineering effort was started.

PDIC Reverse Engineering: Optical

Using an IC inspection microscope, a die shot of the PDIC was produced. This could be used to get a better idea of the internal structure of the device. This was made way easier by the fact that it is an optical integrated circuit, and is therefore housed inside a clear plastic package with good optical properties, suitable for direct microscope inspection without decapsulation. The picture below could be used to identify some functional blocks of the circuit, however full tracing of the bondpads through internal circuits to the diode quadrants was considered unfeasible. However, it became apparent that the PDIC seemingly houses at least independent 8 photo diode channels. (Four quadrants in the center square, and at least two segments for each of the outer squares).

TODO Picture

PDIC Reverse Engineering: Electro-Optical

To facilitate Pinout reverse-engineering of the IC, a simple test fixture was soldered. This gave easy access to any of the pins. On most of the pins, some effect to applying LED lighting could be identified. Initially, the output behaviour was simply classified:

- Low light sensitivity: 4 outputs
- High light sensitivity: 4 outputs
- Same magnitude, but opposite polarity outputs: 2 pins
- Negative output voltage: 1 pin

It was conjectured that the smaller inner quadrants were responsible for the low-sensitivity outputs, while the outer segments would produce a large amplitude (due to their larger light collection area).

In a second stage, the exact pinout was determined by means of selective illumination: For any given test, two IC output pins were compared using two DVMs, and an aperture was slowly moved along the surface, either vertically or horizontally. Normally this would result in reduction of the output voltage for one of the outputs earlier than for the other one. In this way, the positional relationships between all output pins could be resolved, forming a final assignment of diode quadrants to output pins.

TODO Picture

The output producing negative voltages is not considered to be useful in the final application, while the differential output pair is likely a summed output of the four inner quadrants (the RF output).

With the assignment of pins to diode quadrants done, the OPU could be modified to fan-out the required connections to custom electronics

OPU Modification

A breadboard header was added to the OPU, fanning out all required signals to the custom electronics on a ribbon cable. The analog output signals are separated on one side, while the current inputs for the laser diode and the lens actuators are kept to the other side. This should help mitigate electrical coupling between these signals, even though the diode outputs are actively driven by the PDIC.

TODO Picture

Electronics

TODO PCB-Design

FPGA Design

TODO FPGA-Design

Software

TODO Software