Turkish Online Journal of Qualitative Inquiry (TOJQI)
Volume 12, Issue 10, October 2021: 2314-2326

Study Of Dvd Player Components For Developing Cost-Effective Confocal Microscope

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Abstract

Confocal microscopes can provide depth-based imaging which can be useful in detecting skin cancers in early stages. However, confocal microscopes are very costly and are not easily available. To solve this problem, a study on the optical and electrical components of discarded DVD players have been done to prove their usability in a miniature, and cost-effective scanning confocal microscope. The Optical pickup of DVD players is studied to be used as the light source and detector for the microscope. A single mode fiber is used to carry the laser light from the source to the sample and back. The single mode fiber also works as a pinhole, satisfying the confocal condition of the microscope. Electrical components of DVD players have been used for developing a scanner stage. Several experiments have been performed which prove the workability of the setup.

Keywords: Early Cancer Detection, Confocal Microscope, DVD Players, Depth Imaging, Lasers

Introduction

Confocal microscopy, also known as Laser confocal scanning microscopy (LCSM) is an optical depth-based imaging technique. Confocal microscope uses laser as light source and bases its operation on a focal point, using a pinhole to collect light reflected from the focal point. The pinhole blocks the out-of-the focus light (Oh et al., 2019). Confocal Microscopy can be used for multi-depth imaging of biological tissues (Olsovsky et al., 2013) & (Ishiguro & Horimizu, 2008). The depth-based information obtained from biological tissues using a confocal microscope, can be used for early detection of certain types of cancers, especially skin cancers (Borsari et al., 2016), (Jain et al., 2018), (Rajadhyaksha et al., 2017), (Sahay et al., 2017), (Al-Arashi et al., 2007), and (Larson et al., 2013). But confocal microscopes are very costly, and are not easily available everywhere. To solve this problem, a study has been performed on optical and electrical components of discarded DVD players, which may be used for the development of a compact and cost-effective confocal microscope. The Optical pickup (or scanning head) of a DVD player contains diode lasers, photodetector IC (PDIC) and necessary optics to focus light on the object. Optical pickups can be used as the source as well as the detector for our confocal device. Electrical parts of DVD player like DC motor, permanent magnets and electromagnets can be used to design a scanner for the microscope. For better understanding of the work, we would briefly discuss the working of a DVD player, different optical components in an Optical Pickup and their function.

Working of a DVD player

The DVD and CD disks have pits and bumps in their circular track which carry the information, which is read by the optical scanner of DVD or CD player and converted into video, audio, image or other data files. Optical pickup is the most important part of a DVD player that houses lasers, PDIC, optics and focussing mechanism for reading a DVD disk. An objective lens focuses the laser beam onto the disc; a polarizing beam splitter allows the laser light to be guided to the disc and reflected light to the photodetector array with the help of a turning mirror. Different sections of the photodetector IC (PDIC) are used for data reading and tracking.

Optics and electronic components inside the optical pickup of an Xbox360 HD DVD reader shown in the Figure 1. 1 &2 are 650/780nm and 405 nm Laser Diode respectively. 3 is multisegmented LCD panel for wavefront aberration correction. 4 is a photodetector IC (PDIC). 5 is a turning matrix. 6 is a beam-splitter (half silvered mirror). 7 is a dichroic cube beam splitter. 8, 9 and 12 are collimating, expanding and focussing beam splitters respectively. 10 & 11 are diffraction grating with for selecting different wavelengths.

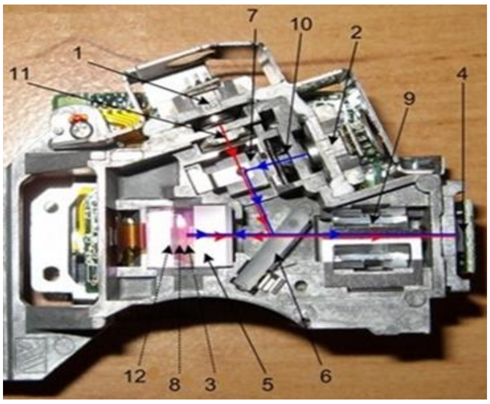


Figure 1. Optics and electronics of a DVD Optical pickup

Optical pickup should be able to move up and down to achieve focus on the discs. Focussing is achieved by magnet pieces and a focussing coil. A tracking coil which is wound around the same magnetic pole piece as the focussing coil is used to move the pickup lens in horizontal direction to read the data without error. The tracking coil can normally move the lens 0.15 inches either side from its point of rest. Larger movement of the optical pickup is driven by a screw drive mechanism driven by a sled motor. A DC motor fast rotates the disc in order to enable the optical pickup to read the data from the disc's circular tracks. The amount of current in the tracking and focussing coils is determined by the feedback signal from the specific photodetector section of the PDIC dedicated to tracking and control.

Literature review

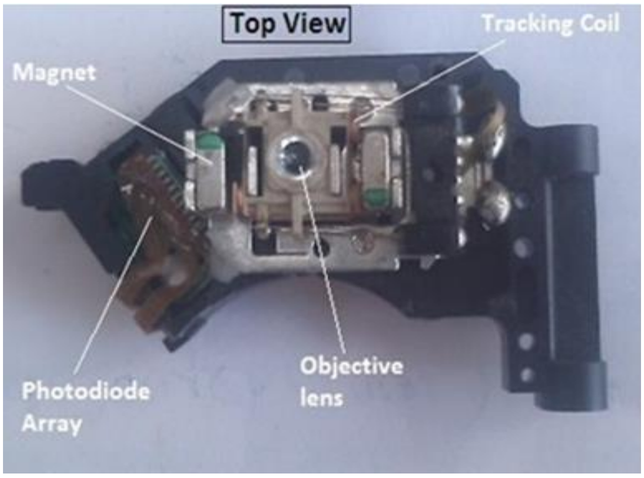
In the quest to develop a cost-effective miniature device for normal and confocal imaging, CD and DVD optical heads have been utilized by some groups. The following papers discuss the development of imaging devices utilizing CD player's optical and mechanical resources.

(Ferrari et al., 2010) demonstrated the high resolution and fine focussing capability of a cost-effective microscope, developed using the optical pickups of DVD/CD players. (Benschop & van Rosmalen, 1991) developed a compact scanning optical microscope (SOM) which was made out of the Compact Disc (CD) player parts. The SOM utilizes the compact disc reading head as a microscope and its scanning mechanism is based on a DC motor, permanent magnets, and an electromagnet. The Compact SOM can measure object-induced amplitude and phase changes of the light. This SOM combines the advantage of scanning-beam and scanning-object microscopes. The reading head consists of light source, optics to focus light on the object, and detectors. Because of the low weight of the reading head, it is possible to scan the entire microscope with respect to a stationary object. Laser light is guided through a single mode fiber to the reading head which focuses the light on the object. designed and constructed a scanning optical microscope (SOM) which was based on the optics and scanning mechanics of a Compact Disc player. They modified the components of a CD player to achieve a light and effective scanning mechanism. Optical pickup (or light pen) which is a part of the CD player containing diode laser, detector and other optics was used as a source and detector for the SOM. The microscope can measure amplitude and phase changes in order to construct an image and is also equipped with autofocusing. (Dabbs & Glass, 1992) replaced conventional clear aperture pinholes in confocal microscopes, by single mode optical fibres and therefore reducing the dust contamination and alignment related problems. Using a single mode fibre also enabled greater flexibility in placing the electronic and optical elements. Two single mode fibres (4-µm diameter each); first at He-Ne laser source and second at the detector end are used along with a beam splitter, a collimating lens and two objective lenses. The beam splitter reflects the reflected and scattered light from the object towards the second fibre. One end of both the fibres works as a pinhole.

Study of Optical pickup and schematic diagram of the proposed microscope

Study of Optical pickups

Optical pickups are the heart of DVD players. They contain optical and electrical components that help in reading the data from DVD disk. Optical pickups from discarded DVD players have been collected for this study. Figure 2 shows the DVD Optical pickup and its components, visible from outside.



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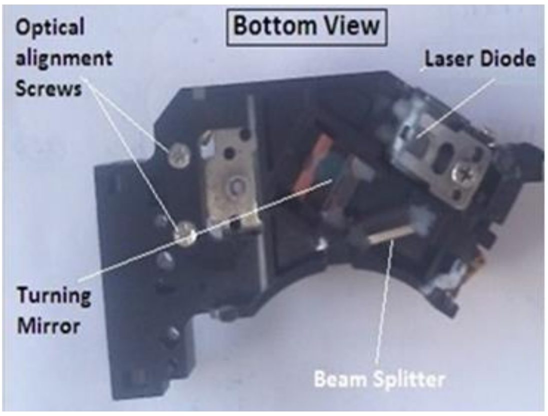


(b)

Figure 2. DVD Optical pickup (a) top view and (b) bottom view

Because of the variable thickness of various compact disks, the lens of the optical pickups should be able to track and focus on the disks. Tracking and control is achieved by the feedback signal from PDIC and focussing is achieved by the magnet pieces and a focussing coil as shown in Figure 3.

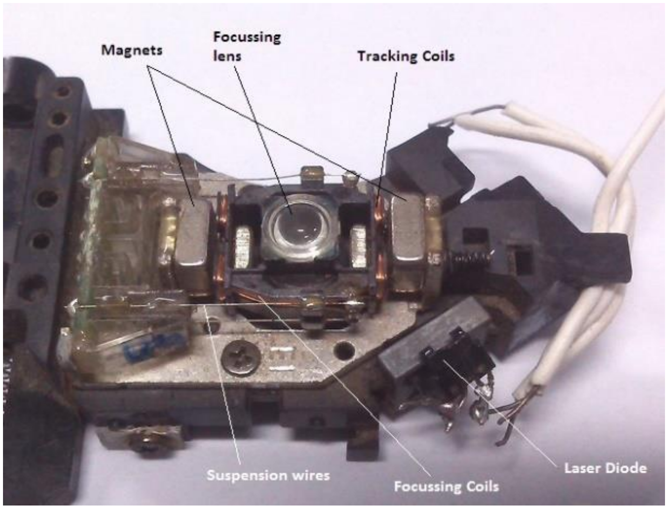


Figure 3. Tracking and focussing system in optical pickup

In this paper, it will be verified if the combination of laser diode, PDIC and optics of an Optical pickup could be used as a compact source and detector module for the proposed confocal microscope. Also, we have used the electromagnets, permanent magnets and DC motor from the DVD players for the development of a scanner for the proposed confocal microscope.

Schematic diagram of the proposed confocal microscope

Optical and electrical components of a DVD player, along with a single mode fiber and some optical lenses can be used in the development of a confocal scanning microscope. The laser diode in the optical pickup can be powered externally by making electrical connections to its pins. The laser light which is focused by the external focusing lens of the optical pickup can be coupled to a single mode fiber. Biconvex lens and objective lens setup could be used on the other side of the fiber to focus the light on the sample. Figure 4 shows the schematic diagram of the proposed confocal scanning microscope.

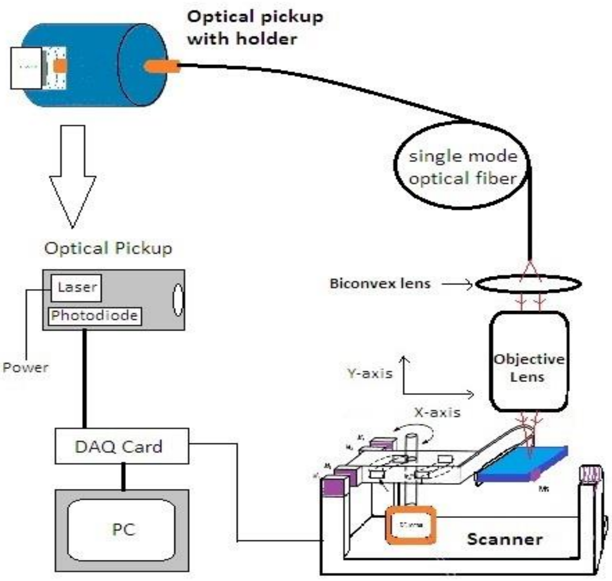


Figure 4. Schematic diagram of the confocal scanning microscope

In this paper, source and detection component of the proposed confocal microscope is studied using the Optical pickup of DVD players and its workability is verified. Different methods have been studied for the development of a scanning mechanism. Finally, a scanner platform is developed using the electromagnets, permanent magnets and DC motor from the DVD players.

DVD Optical pickup as source and detector

The laser diode of the optical pickup is used as a source of light. The photodetector IC (PDIC) embedded on the optical pickup has been externally connected and tested to work as a detector. The optics of the optical pickup helps to focus the light to a definite point outside and drives the light coming back into the optical pickup to the PDIC.

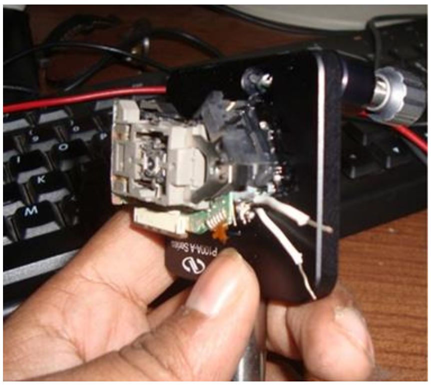


Figure 5. DVD optical pickup's laser diode with wires connected

External wires are connected to appropriate pins of the laser diode as given in Figure 5. The red laser diode which has a sharp spectral peak at 657 nm, is used as light source.

The Photodetector IC (PDIC) which comes embedded in the Optical pickups has been tested to be utilized as a detector for confocal microscope. Identification of the pins on the PDIC's was difficult;

hence experimental methods have been applied to verify their pins by comparing them to the datasheets available on the internet. Most PDIC's found in different optical pickups have 12 pins and they all match 12 channels Sipex SP8042 PDIC. To study the optical response, PDIC's are extracted from optical pickups and external connections are made by soldering fine wires on its pins. The PDIC's are reattached to their original position in optical pickups once the external wires are connected. Figure 6 shows the PDIC with fine wire connections and its microscopic image taken in lab.

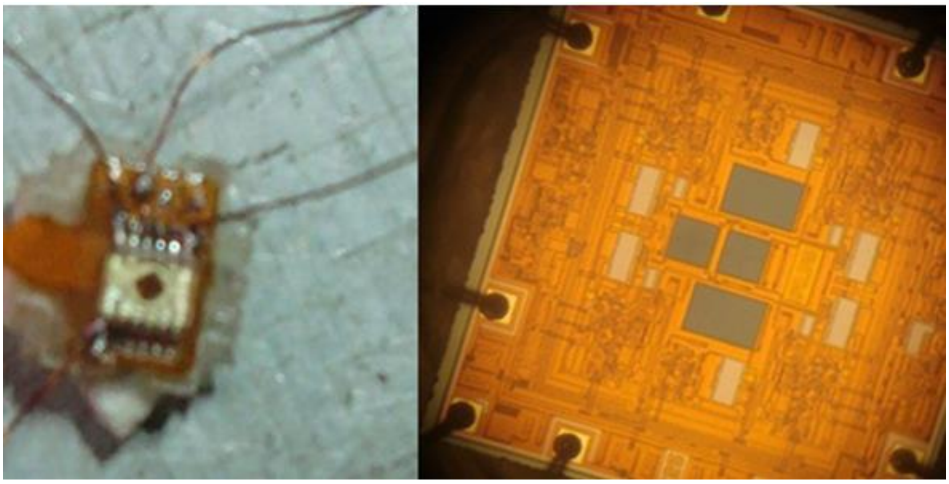


Figure 7. Wire connections of PDIC (left) & its image taken in a microscope (right)

Experimental setups

Coupling laser light to the single mode fiber

We have used a single mode fiber to carry the light from optical pickup to the object site. The single mode fiber is cleaved on both the ends using a cleaver. One end of the fiber is put to the site where laser light is focused by the optical pickup. A very fine XYZ positioner has been used to place the fiber tip on the right place in order to achieve maximum coupling.

Specifications of the single mode fiber: fiber diameter (core + cladding) = 124.8 microns, Numerical aperture = 0.16, Mode field diameter = 3.2 microns @ 633nm, Beat length = 1.5 mm @ 633nm, Core concentricity = 0.51 microns.

We attached the optical pickup on a mirror mount or an XY positioner using an adhesive glue. The single mode fiber (after cleaving) is put in a fiber holder and fixed over a fine XYZ positioner. Other side of the fiber is put in a cylindrical fiber holder and its tip is put almost in contact with a photodiode (DET10A biased silicon detector). The photodetector is connected to a CRO through a BNC cable. The experimental setup is shown in Figure 7.

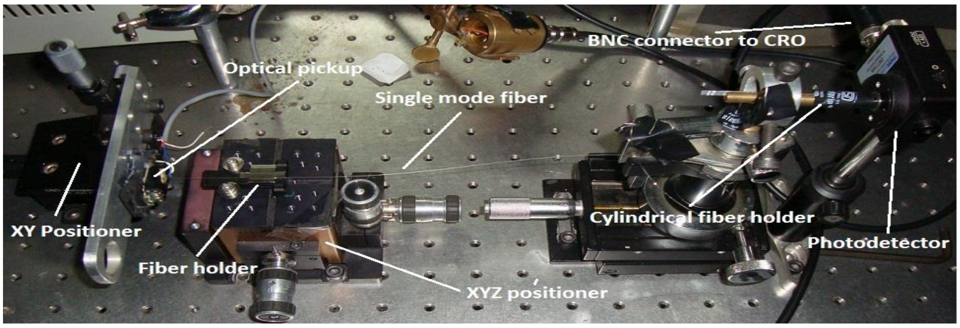
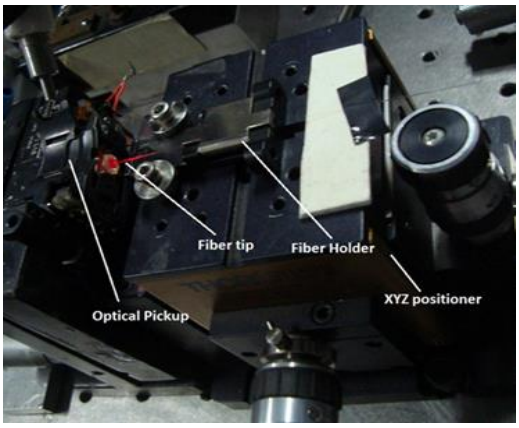


Figure 7. Optical pickup and single mode fiber light coupling setup

As shown in Figure 8 (a), the tip of the fiber has to be adjusted meticulously to a point where optical pickup focuses the laser light. X, Y and Z positioning knobs of the XYZ positioner are rotated to achieve maximum coupling of the light into the fiber, which is observed on CRO.



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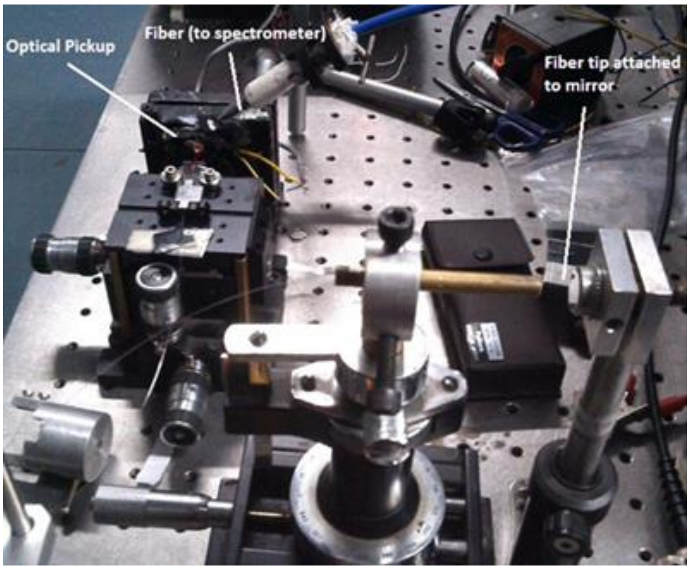


(b)

Figure 8. (a) Coupling of light into the single mode fiber (b) Mirror attached at the other end of fiber to see reflection

After we achieve the maximum coupling, the photodetector was replaced with a mirror to see the reflected light into the optical pickup. The mirror was almost attached to the fiber tip as shown in the Figure 8 (b).

Confocal setup with biconvex and objective lenses on the object side

After achieving reflection from a mirror attached to the object side of the fiber tip, a setup with a biconvex lens and objective lenses is made and again, reflection from a mirror is recorded. The specification of the biconvex lens and the objective lens are as follows:

Biconvex lens: Focal length = 3 cm, Diameter = 8 mm; *Objective lens:* Model name: Labomed LP4x Semi Plan Achromat, Working distance = 8.83 mm, 4X magnification, Numerical aperture = 0.10. Figure 9 shows the full confocal setup with biconvex and objective lenses.

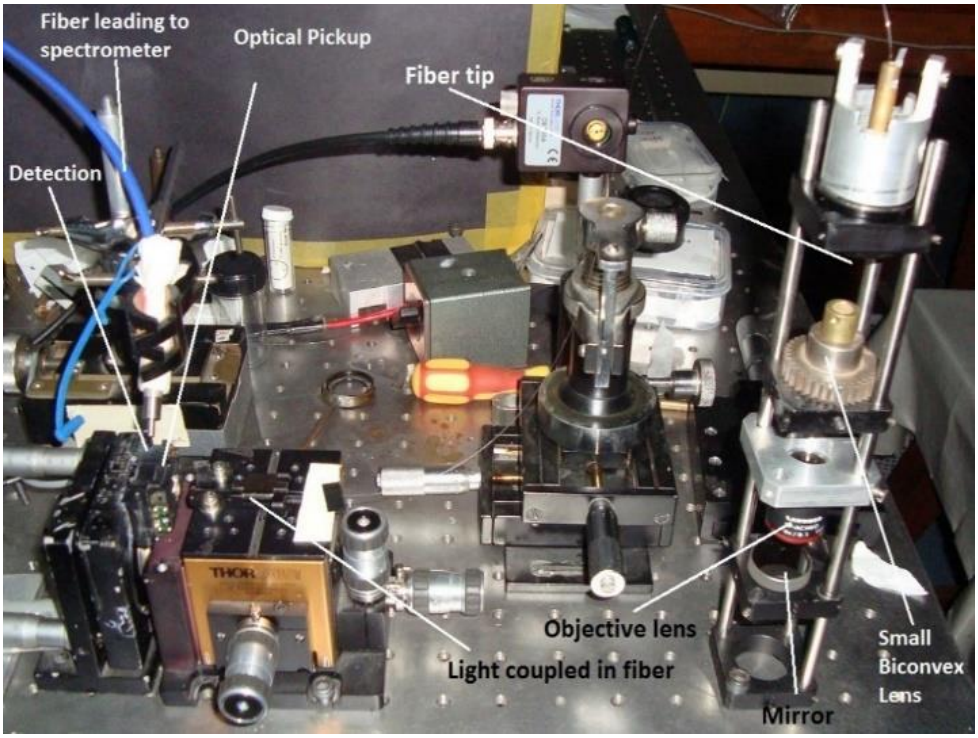


Figure 9. Confocal setups with biconvex and objective lens

Development of scanning platform

Several methods have been studied to develop a scanning mechanism for the proposed confocal scanning microscope. These methods included using stepper motors, piezo electric tubes, piezo buzzers, and a technique involving a DC motor, some magnets and an electromagnet.

A scanner platform is developed, which is based on compact disc technology using a DC motor, 5 permanent magnets and an electromagnet. All the above-mentioned elements have been fetched from discarded DVD players. This scanner is a modified version of the scanner used by (Benschop et al., 1989) in their miniature scanning optical microscope based on compact disc technology. The modified scanner has a scanning platform (where object is placed) in place of optical pickup.

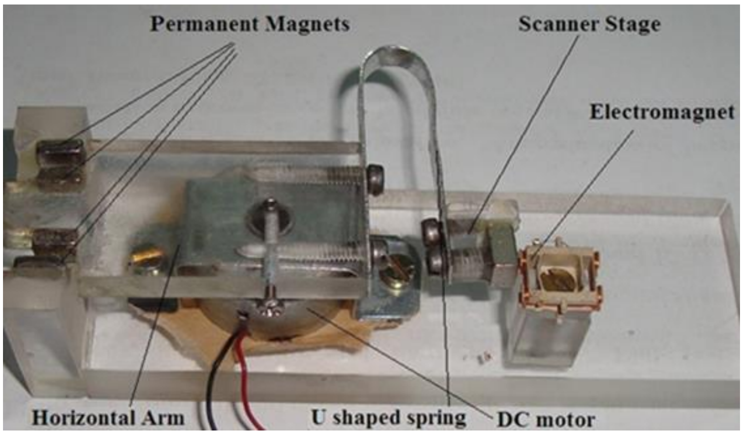
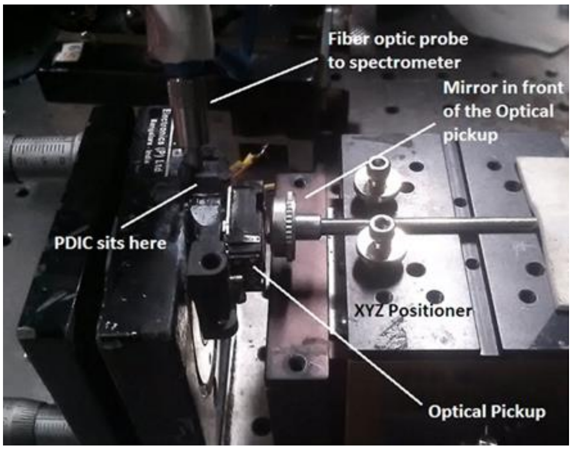


Figure 10. Scanner based on compact disc technology

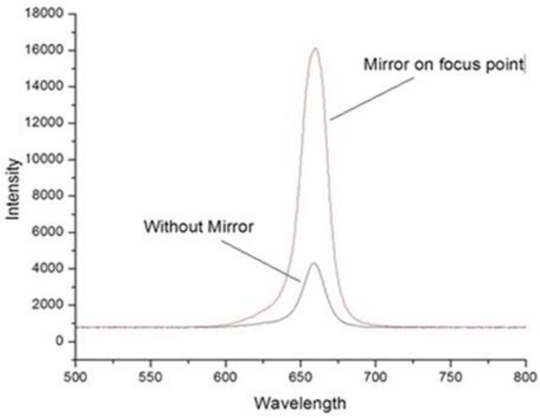
As shown in Figure 10, the scanner has a DC motor, 5 permanent magnets and an electromagnet. All these elements have been extracted from discarded DVD players. A horizontal arm is placed on the DC motor. One side of this arm contains permanent magnets and other side has a U-shaped spring on which the scanner stage is fixed. The permanent magnets on one side of the horizontal arm keep it in in the zero position in y axis, and when we give a voltage to the DC motor, the arm will try to move in the y axis direction. Since the scan area is very small, the movement of the arm in y axis will be almost linear. The U-shaped spring helps the movement of the scanner stage in x axis direction by using an electromagnet and a permanent magnet setup. When the electromagnet is given a voltage, it pushes the permanent magnet attached on the scanner stage.

Results and discussions

To check the workability of Optical pickup as a source as well as detector, we first put a mirror at the focal point in front of the Optical pickup to check whether the light reflected from outside the optical pickup is driven to the PDIC location or not. To collect the reflected light, a fiber probe has been put in the location of PDIC and high-resolution miniature fibre optic spectrometer (HR2000) from Ocean optics is used to record the intensities in arbitrary unit (a.u). The setup is shown in Figure 11 (a). The graph is plotted in Origin pro 8 software and shown in Figure 11 (b).



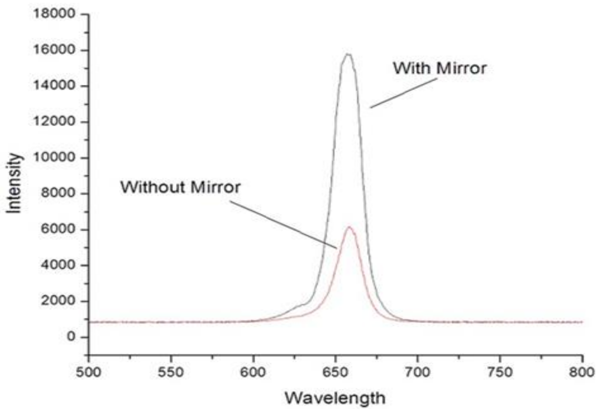
(a)



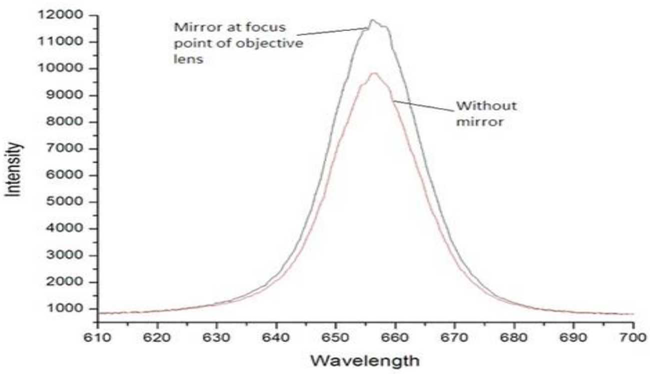
(b)

Figure 11. (a) Mirror experiment setup (b) light intensities at PDIC location, with and without mirror

Now a single mode fiber is used to carry the light from Optical pickup. A mirror was placed at the other end of the fiber to see the reflected light into the optical pickup. Figure 12 (a) shows the intensities of light with and without mirror. Whatever intensity we get without mirror is because of the reflection from the fiber tip at the optical pickup focus point and background.



(a)



(b)

Figure. 12 (a) Intensities of reflected light with and without mirror attached to the other end of the fiber tip (b) Intensity of light with & without mirror at the focus of objective lens

After achieving reflection from a mirror attached to the object side of the fiber tip, a setup with a biconvex lens and objective lenses is made to collect reflected light from the focal point of the objective lens. A mirror is placed at the focal point of the objective lens and the intensity of the reflected light is recorded as shown in Figure 12 (b). The summary of the mirror experiments results has been shown in table 1.

Table 1: Summary of mirror experiments results

Experiment	Light intensity (a.u)		Percent change
	Without mirror	With mirror	
Opm [a]	4250	16000	276%
Fib [b]	6100	15950	161%
Obj [c]	9800	11900	21%

[a] *Mirror at optical pickup mouth*

[b] *Mirror at fiber tip*

[c] *Mirror at focus of objective lens*

These experimental results prove that the light from optical pickup laser can be coupled into a single mode fiber and the reflected light from the focal point of the objective lens at the other end of the fiber can be collected and guided back to the PDIC through the same fiber for measurements.

To check the workability of the PDIC, it was biased according to its pin diagram with Vcc = 5 volts and Vs = 2 volts. Vcc is the supply voltage, Vs is the biasing voltage for photodetectors in the IC, and V_{rf} is the sum of one of the four central photodetectors. Output from V_{rf} pin has been recorded by incidenting light from a red diode laser. The PDIC showed variation from 1.26 volts when in zero light condition to 1.72 volts when incidented upon by a red diode laser light directly. In addition to these experiments, a scanning platform is also developed based on compact disc technology using a DC motor, 5 permanent magnets and an electromagnet taken from DVD players. The scanning platform works well when manually connected to the supply voltages.

Overall, these experiments and scanning platform development prove the workability of optical and electrical components of DVD players in the development of a compact and cost-effective scanning confocal microscope. A full-fledged cost-effective miniature scanning confocal microscope is under development.

Conclusion

Skin cancers, and Cervical cancer develop (in the form of squamous intraepithelial lesions) from the basal layer of epithelium and spread to its full thickness before becoming invasive. To detect the cancerous lesions in early stages, a miniature confocal microscope can provide depth-based information of a tissue sample. Towards this goal, a study on optical and electrical components from DVD players has been done for their utilization in developing a scanning confocal microscope, with an effort of making the system simple, physically compact and cost-effective. Accordingly, optical pickups and electrical components from discarded DVD players have been studied for some of the basic design elements of the confocal microscope. The Optical pickup of the DVD player is studied to be used as the light source, as well as the optical detector for the microscope. A single mode fibre is used to carry the laser light from the source to the sample as well as the collected (reflected) light from the sample back to the optical detector. Furthermore, the same single mode fibre plays the role of the pinhole for the collected light, thereby satisfying the confocal condition for the microscope. Several simple experiments have been performed in order to test the workability of the setup while mechanical and electrical designs made and implemented towards building the final setup. The results of these experiments have been positive and establish the viability of the device to a large extent. Together with development of the light source, detection scheme, and design and implementation of a fibre-coupling setup, a sample scanner, based on compact disc technology has been developed using DC motors and magnets, from discarded DVD players. Based on the positive results of these experiments, a full-fledged scanning confocal microscope will be developed in future.

Acknowledgements

We are very thankful to Dr. Asima Pradhan and Dr. Saikat Ghosh for their invaluable support and guidance in the execution of this project. We also thank Dr. Anurag Shukla for his help in writing this paper. No funding was received for this work. The authors declare no conflict of interest.

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