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A Survey of Smartphone-based Fluorescence Microscopy Technology

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1. Abstract

Electrical engineering is a field of science dealing with designing of different types of models and apparatus. The paper focuses on the procedures and necessary techniques in the development of a Handheld Smartphone Fluorescent Microscope (HSFM). The HSFM may have a variety of engineering applications. However, the main function of the HSFM in relation to this paper is concerned to develop microscopes that can be used as a blue light detector using the underlying concepts of bio-detector. The device has a wide range of applications and it is normally fixed in electronic gadgets such as mobile phones, specifically at the cameras. The convenience of the device when used on mobile phones is based on their small size enhancing portability unlike other bigger versions.

In general, microscopes are used to magnify images or objectives, which is one major role of these devices. However, Fluorescent microscopes have a wide range of use beyond just simple magnification of objects. Such types of microscopes play roles such as the photographic capture and recognition of molecules with near similarity in cell physiology. Its ability to distinguish between two close cells is based on the extremely higher resolution compared to other types of microscopes. With the latter application in mind, the technology used to design fluorescent microscope works to integrate electrical engineering with medicine. The paper focuses on different techniques applied in when designing such microscopes.

A significant feature aspect of the research process discussed in the paper is the necessary apparatus and procedures used in the manufacture of the gadget. Besides, such projects usually attract some specific amount of capital input. Therefore, there is a need to include the cost of the entire research in the paper. In addition, the paper has incorporated an in-depth report and analysis of findings in a logical manner for easy synthesis by readers. In the data analysis part, the use of accurate data and other visual presentations have been utilized to bring out a clear relationship between textual and visual information. Ultimately, the research paper herein is a proposal of a unique design of fluorescent microscope.

2. Introduction

The application of fluorescent microscopes in the biomedical field is one of the greatest achievements due to its efficiency and convenience of use. The device is also cost-efficient and fast compared to other types of microscopes, making it the best option during complex cell analysis. The older versions of fluorescent microscopes only differ in size and play the same role as the newer versions. The older versions are large and inconvenient when it comes to portability (Coskun et al., 2011). However, the new versions are portable hence, increasing the convenience of use during complex cell analysis and medical diagnosis of diseases. Arguably, the applicability of any electronic device is based on various factors such as cost, efficiency, portability and compatibility with other devices. Some gadgets may be efficient when it comes to features, but it may fail to be compatible with other devices (Min et al., 2013). However, modern fluorescent microscopes have been developed to be compatible with a number of electronic gadgets such as Smartphone and cameras. The compatibility is based on both functionality and size that makes the devices fit into the desired electronic devices. The introduction of the modern fluorescent microscopes would improve Smartphone technologies all over the world by ensuring quality devices at affordable rates.

The application of microscopy in biomedical and clinical fields has been quite challenging in the past years due to some disadvantages associated with the old ancient microscopes. However, the role of the microscopes in imaging and scanning of cells is one advantage that has really assisted in various studies in the medical field. The introduction of the modern fluorescent microscopes has improved the identification of cells, proteins and other molecules (Tosi et al., 2011). Unlike the traditional microscopes, the modern fluorescent microscopes have heightened clinical experience due to the high level of accuracy and sensitivity of the microscopes. The modern microscopes provide a clear view of internal organs, cells and molecules. Therefore, medics find easy time diagnosing different infectious cells without any confusion (Alvarez-Uria et al., 2012). The struggles by scientists to create instruments that can be used to make out clear cell physiology using microscopy have greatly improved the development and improvement of fluorescent light microscopy over years.

Application of the technology in photography is another important move that has advantaged many electronic companies dealing in cameras and Smartphone. Arguably, Smartphone users, specifically, are concerned with recreational services such as music and photography offered by the companies producing the gadgets (Korzyńska & Iwanowski, 2012). Therefore, quality phone cameras are one of the factors considered by consumers when buying Smartphone. As a result, leading Smartphone industries

such as Samsung, Apple and OPPO have incorporated the concept of fluorescent microscopy in designing the phone cameras. The technological advancement in lenses, sound system, battery capacity and software improvements are some of the leading reasons for introducing new model of Smartphone regularly by the companies. Specifically, the quality of the phone cameras has been increasing across different models introduced by every company. The good camera experience is due to the electrical engineering techniques used in designing fluorescent microscopes that are used to improve the quality of phone cameras. The mentioned applications of fluorescent microscopy are just some of the few uses, with the technology gradually improving to better the experience in various fields (Fei et al., 2016). Thus, it is important to understand the underlying concept behind the functionality of the modern fluorescent microscopes.

2.1.Types of Fluorescence Microscopes

Fluorescence microscopy involves lighting the sample and then detecting fluorophores emitted with certain wavelengths of light spectrum. Therefore, it starts with the origins of illumination. The challenge is to regulate the input amplitude or anticipation light. The higher the measurement, the more fluorescence returns or pollution.

a. **EPI fluorescence microscopy** - There are three key choices for microscopists: white light, LEDs, or lasers. The whole collection of so named epifluorescence microscopes was lit by arc lamps and LEDs. Gases such as vaporized mercury and white light discharge are used in the most popular light source, Lamps. Then one or more filters should be added to the microscope that narrows the spectrum down to the desired wavelength, for example, to excite a green fluorescent protein in the sample. These microscopes are able to photo bleach the entire sample in light at the same time (Dance, 2017). Before using the microscope, the bulbs require a little longer to warm up, and usually last a few hundred hours until they fade out. As they decrease, it is difficult to compare experiments conducted even several weeks apart with different intensities. The lamp expense would be $100 or more. LEDs are yet another, relatively new and quite popular suggestion. Growing LED in a small part of the spectrum thus needs less sorting than when dealing with white lamps. The LEDs need less fuel, do not fade after thousands of hours and do not need time to warm up or cool off relative to arc lamps. They also simultaneously bathe the whole sample in light, but are typically not as strong as bulbs, so they have less potential to cause photo bleaching. They are in the region of a few dollars and are cheaper than candles.
b. **Confocal microscopy** - When people reach the whole sample with incoming light, like epifluorescence microscopes, fluorophores above and below, the target visual plane gives

color and restricted resolution. Confocal microscopes utilize laser light to solve this obstacle. They will concentrate the illumination on one stage using mirrors, such that fluorophores are not activated elsewhere in the sample. There is also a pinhole display at the end of the exposure to guide the light from the sample to the appropriate direction. The machine analyzes that link of excitation light across a plane in laser scanning confocal microscopy provides a cross-cutting image of epifluorescence. The disparity between the plane's rates leads to a "pack" of photographs at various depths that give one an understanding of the 3D structure of the object. Confocal laser scanning is only a confocal microscope version. The exciting light from laser or Epifluorescent source is, by contrast, shone through multiple pinholes by the spinning disk and programmable array microscopes. This benefits from the ability to acquire a picture quicker, which may be crucial to imaging activities in living cells. However, lasers last a long time, maybe a few thousand hours like LEDs. Lasers are thousands of dollars' worth of expensive light source (Dance, 2017). Confocal microscopes use a photo multiplier channel to track and enhance the low emission radiation. Particles received first hit a photocathode that absorbs a photon and produces an electron. Each electron communicates with a number of electrodes, each releasing more electrons than consuming them. The effect is signal enhancement.

c. **Super resolution microscopy -** Super Resolution Microscopy makes it easy to image the light microscope below the (resolution) diffraction mark. In the transition to a sensor, the wave structure of light can make an insignificantly tiny source of illumination blend into a 200-300 nm region. This implies that the resulting photo comprises two or more objects lie beyond the boundary of diffraction. A range of methodologies that allow for sub diffraction limit pictures have been developed over the last two decades. These techniques typically increase light microscopic resolution by 2-10x. This type of microscopy is a series of optical microscopy techniques which enable such images, due to light diffraction to have resolutions higher than those imposed by a diffraction limit. Super-resolution imaging techniques rely on the near-field region (photon tunneling microscopy as well as on the near-field optical microscopy and the Pendry Superlens).

d. **Fluorescent Widefield Microscopy -** The most common and simplest form of fluorescence microscope is the fluorescent broad field microscopy. The microscope target, collimated (non-converging or diverging) anticipation illumination illuminates all (wider) views equally. Light source to the target is captured and projected on a picture sensor. The lighting of a sample is

called the lighting of ‘Epi’ in the opposite direction of the fluorescence range. That is why they are called Epi-fluorescence microscopes occasionally.

e. **Two Photon Microscopy –** Two-Photon Microscopy tries to address two widescreen and confocal microscopic drawbacks. The first is broad-ranging and confocal microscopic light excited by a sample’s entire axial length. Therefore, because all fluorophores are collected by a wide number of optical slices in the sample, then even those in the focal volume are continuously exposed to light. These results in quicker photo bleaching and less signal power**.**

f. **Light Sheet Microscopy -** Light blade microscopy generally uses two or three lenses in a configuration to create a narrow blades of anticipation light, which extends parallel to a fluorescent imaging purpose. Just as for 2-photon microscopy, only one target plane of the sample, reducing photo bleaching, is excited at a time. Like widefield, the entire field of view is simultaneously excited and captured with a single exposure of the sensor. This is much quicker than the use of raster scans in confocal or 2-photon microscopes.

g. **Total Internal Reflection Microscopy (TIRF) -** Full Internal Reflecting Microscopy (TIRF) is a technology used to activate only beside the surface of a very thin film of fluorescent molecules. Light is transmitted at an angle across the overlay to the degree that the material is entirely mirrored in the connection between the glass surface and the water buffer. This reflection happens as a result of the refractive index difference between the glass and the sample’s water-like buffer. Besides, if the thrilling light is entirely absorbed, the energy in the sample is released into an evanescent stream, and just a few hundred nano-meters from the sensor glass and water excite fluorophores.

h. **Parallelized Confocal Microscopy (Spinning Disk) -** Parallelized confocal microscopy (Spinning Disk) speeds up the acquisition of a spectroscopy picture. Organizing a pixel image is slow, and consequently standardisation is used to boost quality by some confocal microscopes. A metal disc with a set of holes is revolving along the stress light direction of spinning disk microscopy. Each hole is equivalent to a separate sample location. The picture can be acquired quicker when more than one hole is lit at a moment.

3. Literature Review

Distinct scholars and analysts have been able to present different studies on lens formation. A study by Bo Dai and other professionals shows detailed procedures used in the application of liquid polymers. The article titled ‘Writing in light’ shows the process used by the authors to create an integrated database that would be used to design two-droplet lenses. The two-droplet lenses would be dyed with a colored solution for easy visibility (Fenton et al., 2010). The team’s research was successful following the creation of lenses that were compatible with a variety of electronic devices such as Smartphone and cameras. Besides, the lenses had high resolutions that enabled the team to distinguish clearly between close cells during observations. The cost of the entire project was manageable, a factor that enhanced other activities such as actual counting of cells, tissues, and tumors, as well as monitoring of genes tagged fluorescently (Kazemifar et al., 2016). The findings of this study highlight the importance of fluorescent microscopy in multiplicity of different fields of knowledge and professions. In other words, the concept of fluorescent microscopy can be used in a wide range of fields such as molecular and cell biology, environmental conservation, healthcare sector and food industry (Sousa-Figueiredo et al., 2010). The remarkable role of fluorescent microscopy in the biomedical field includes detection and tracking of cells, proteins and other molecules with the view of identifying defective cells.

The concept of fluorescence has obvious similarities to its light separation making use of different optical filters. The main factors considered by electrical engineers when designing microscopes are the resolution and contrast of images. This requires the application of integrated technology to ensure that all techniques necessary to design the modern microscope are understood. Fixing major challenges that are normally experienced in the field of microscopy such as optical diffractions and poor contrast of images requires constant innovations in the field of microscopy. Thus, optical concepts such as light wavelengths, imaging techniques and concepts used in image analysis need to be clearly mastered.

Many studies have shown that the architecture of modern microscopes is based on a variety of techniques to solve certain types of microscopy. With the advancement in technology, different electronic industries are deriving ways of improving the quality and functionality of their devices (Sahu et al., 2014). For example, the modern Smartphone companies are trying hard to improve the quality of their cameras by designing lenses with higher pixels. However, this is only achievable through designing portable and small-sized fluorescent microscopes. The basic concept of designing the microscope is to create a high-tech gadget that can be compatible with other electronic devices. Unlike many types of microscopes, the modern fluorescent ones are highly compatible with gadgets such as Smartphone and other cameras (Li et al., 2010). Evidently, many companies dealing with such gadgets heavily rely on modern fluorescent microscopes due to their advantages over the other types of microscopes.

Some researchers have also presented the technological developments behind which homemade fluorescent microscopes can be designed. The technological advancement is comparable to the ancient idea of the pinhole camera that was later developed to the modern techniques of designing lenses. Similarly, the technology used to design traditional microscopes has been modified over years with an aim of improving quality and efficiency of lenses and cameras (Ghosh et al., 2011). Lenses have a wide range of use beyond photography. Scientific uses of lenses such as in the study of cells require a high-tech approach determined by the magnifying ability of the lenses used in cell analysis (Ettinger & Wittmann, 2014). The increasing demand for resolution, magnifying ability, portability and compatibility of microscopes is a key factor for the invention of fluorescent microscopy. These types of modern microscopes have played a leading role in creating a good working experience in various fields of use. The technology is applicable in fields such as medicine, research and recreational field.

3.1.Design principle

- **One or Two- Photon Fluorescence–**refers to a type of fluorescence allowing only the absorption of single protons, which in turn releases a lower energy photon. The indicators used in this type of fluorescent can receive protons from different sources, but only emit a single proton (Sasagawa et al., 2010). The concept behind these indicators will be understood through studying the behavior of light as it travels in a straight line. The light property implies that only one proton can be transferred from one indicator to another. Although these indicators can receive multiple energies at the same time from different sources, they can only transfer one proton at a time and release low-energy photons. The principle is applied in image production. The light emits techniques must be known to have improved experience and performance by using this principle (Sanderson et al., 2014). The diagram below is a clear presentation of the operating concepts of the photon fluorescent. In the diagram, there are both short and long wavelengths, each having specific amount of energy. The arrows in blue represent lights with short wavelengths while those in red are lights with long wavelengths. Photons from the long-wave lights are having more energy due to the progressive emissions. On the other hand, the blue lights have photons with low energy due to the non-progressive emission (Wang et al., 2014). The difference in the wavelengths between red and blue lights is due to the high concentration of protons at the preliminary stages of photon emission process. The blue light normally has a dim appearance due to the fewer photons on the surfaces of the indicators. However, few photons in the blue lights contain more energy that the many photons in the red light.

Figure 1: Fluorescent Indicators during Excitation

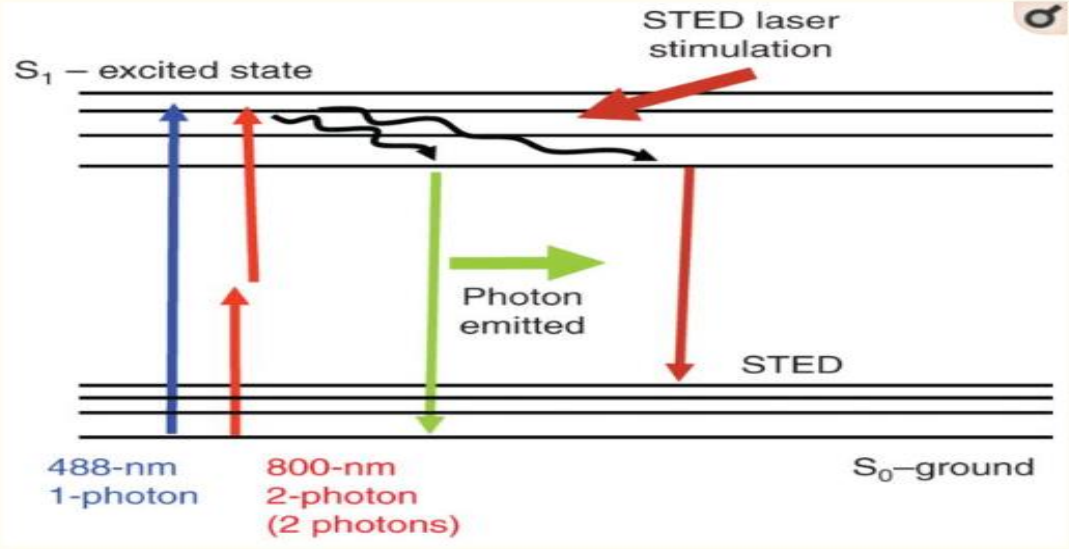


Figure 1

Changes in electron state of fluorescent indicators during photon excitation and emission (Jablonski profiles). Excitation (from S_0 to S_1) induced by 488 nm laser light (blue) requires one photon or by two-photon 800 nm light (red) requires two photons. After relaxation to the lowest energy levels, the reverse transition (from S_1 to S_0) releases a photon of longer wavelength (green). The incidence of photons at 592 nm (STED wavelength) induces the transition from S_1 to high levels of S_0 and suppression of fluorescence.

- **Fluorescent light separation** – the process involves distinguishing blue light with short wavelengths from red lights with long wavelengths. The whole process is termed as excitation and is possible due to the difference in the brightness of the two sets of lights. Red light with long wavelengths has photons that increase their energy because of the photon transfer. The indicators used in this process transfer protons progressively and each successful transmission has a lower energy compared to the previous one. The separation of dim and bright is possible due to the difference in wavelengths and the progressive transmission. Lights with longer wavelengths are visible and can be used over long distances. Applications of such lights are seen in vehicles' headlights. Fluorescent light separation is done using two filters Em1 and Em2 as shown in the diagram below. The basic concept of this technique is based on the use of dichroic mirrors, which have specific properties to absorb light of the required wavelengths. As mentioned before, red lights have long wavelengths and are brighter than the blue lights with shorter wavelengths. Therefore, the red lights are used in the illumination of the specimen. The red light is referred to as the excitation light. During transmission of the bright light using the Em1 mirror, emitted fluorescence is passed to the emission for another series of separation using multiple indicators. The main purpose of the Dm 2 mirror is to separate the emitted fluorescence into two beams while

the emission filters prevent and annul the effects of excess light. The fluorescence with dim light is then absorbed by cameras fixed on gadgets such as Smartphone.

Figure 2: Fluorescent Light Separation

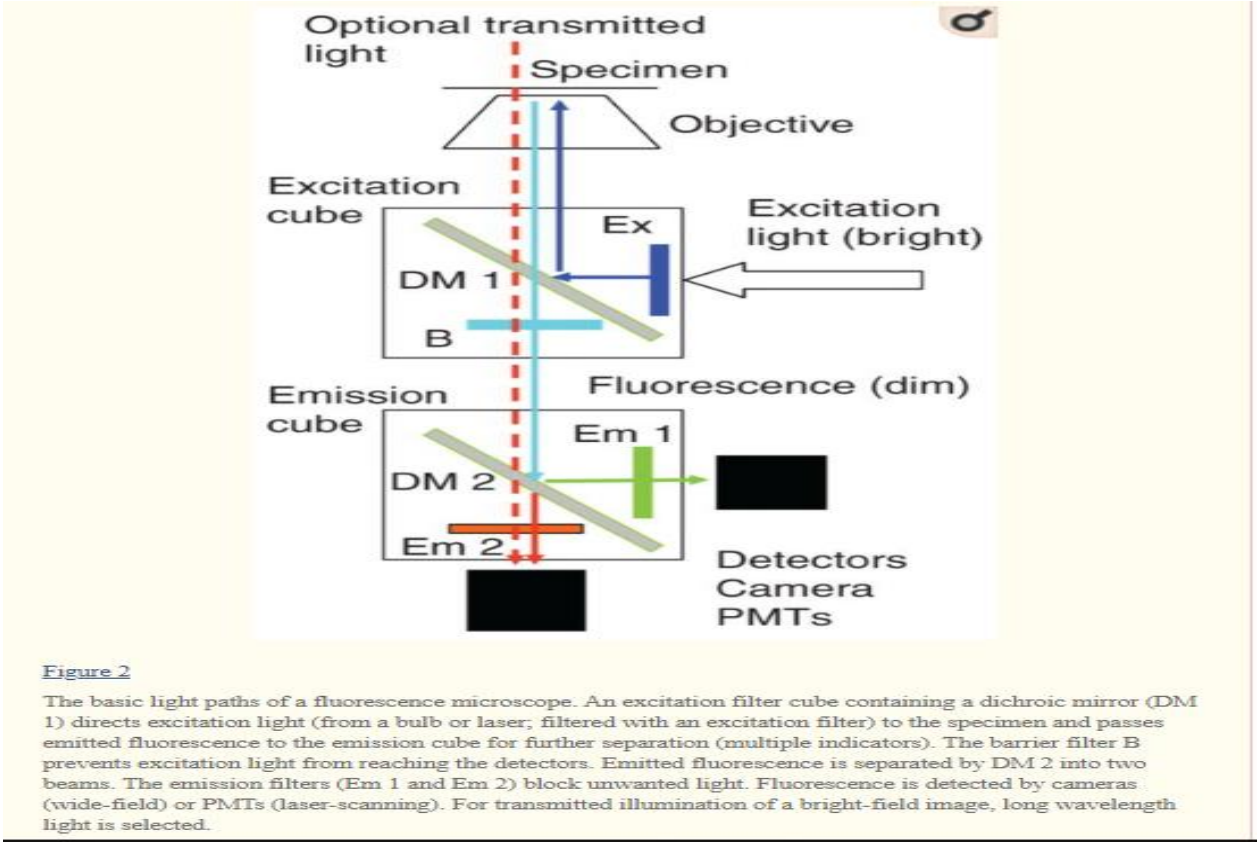


Figure 2

The basic light paths of a fluorescence microscope. An excitation filter cube containing a dichroic mirror (DM 1) directs excitation light (from a bulb or laser; filtered with an excitation filter) to the specimen and passes emitted fluorescence to the emission cube for further separation (multiple indicators). The barrier filter B prevents excitation light from reaching the detectors. Emitted fluorescence is separated by DM 2 into two beams. The emission filters (Em 1 and Em 2) block unwanted light. Fluorescence is detected by cameras (wide-field) or PMTs (laser-scanning). For transmitted illumination of a bright-field image, long wavelength light is selected.

- **Combination of transmission and microscopic Fluorescence**–there is a distinct requirement necessary in presenting visuals with fluorescent qualities. There must be enough quantities of information to ensure that the viewers get full understanding of sample orientation. The visuals presented may emanate from different fluorescent samples and may bear similar distributions. Importantly, visuals of focus should have clear quality of all images transmitted using the technique of microscopy and they should be produced by DIC or a contrasting phase. To ensure this, the fluorescent lights in the main system can be switched off occasionally to create time for modification of the optics. During the process, the specimen under study should be maintained at a specific position since its movement may affect the modification process.

Processes that are more dynamic can be examined using simultaneous transmission of light using different wavelengths that are bounced back and moved by diachronic filters found in a microscope. The production of fluorescent visuals is achieved through an interaction between red light with longer wavelengths and blue lights with shorter wavelengths. Bombarding the two forms of light with varied wavelengths is the underlying principle used in the manufacture of fluorescent visuals. A dichroic mirror with excitatory properties does the reflection of red and blue lights. Another mirror resembling the one used in the separation of indicators will be used to send the green lights to cameras that are regarded to be highly sensitive, which will also attract reflection of red light by another similar mirror. The whole process, however, involves visual documentation, which can be done using advanced technologies. The beads used in this process should be determined and arranged in the required order for better results. The determination and arrangements of these beads aimed at establishing a specific orientation is attainable by making use of visualization of miniature beads that have fluorescent properties for all the two cameras used.

4. Methods and apparatus

4.1.DNA Origami brightness reference

The study involved the use of DNA origami nano bead samples in determining various molecules and particles that could be traced by the sample (Cybulski, Clements & Prakash, 2014). In order to find traceable molecules, particular numbers of nano bead DNA samples were requiring. Specifically, five samples of the nano bead were used in conjunction with about 10-74 fluorescent dyes (ATTO542). The used dyes are normally green in color and are designed to match with the nano bead. The green color of the dye was deliberately chosen to meet the specifications of spectral range of colors. The underlying concept of this spectral range is aimed at organizing optical sensors for monochromic lighting sources, as well as embedding colors with high sensitivities to be detected by gadgets such as Smartphone. Out of the spectral range of light in electromagnetic spectrum, the study only utilized red and green lights due to their suitable wavelengths when it comes to transmission and photon excitation. Monochromic lighting sources used in the set up were to provide the threshold requirement for photon excitation (Zorzi et al., 2011). A close examination of light transmission shows that light of long wavelengths may be concentrated on a metal surface to stimulate photon transmission. Transmitting such lights using monochromic sources would ensure enough energy builds to dislodge protons that in turn carry energy in the process.

4.2.Blue incident light Application

The most important aspect of the process is to provide enough and required light for the illumination of the suitable surfaces to enhance proton transmission. Light in appropriate quantity and colors must be given to optimize illumination and transmission. Therefore, the use of Blue incident light with varied wavelengths and colors is a one of the procedures that will be used to supply the required lights. Theoretically, light has different applications based on frequency and wavelengths. It is important to note that energy obtained because of photoelectric effect of light depends on the wavelengths and amount of energy of the blue incident light hitting a given photoreceptor (Tachikawa et al., 2010). For this experiment, there will be a need to use Blue incident light due to their ability to produce light of different brightness, color and wavelengths that would be used alongside beads and fluorescent dyes. This embodiment would be used as an alternative source of the red and blue lights needed to illuminate the beads and the fluorescent dye. Using artificial light would be advantageous because it is easy to moderate to produce light with desired color, wavelength, and brightness.

Fluorescent lenses are examples of electronic devices that are designed using the modern engineering techniques. The underlying concepts are geared towards improving the existing microscopes by enhancing portability, resolution, and quality. To achieve this, the design of the proposed fluorescent lens would use a specific approach and technique to ensure the desired product is attained. The techniques to be used will be an integration of photoelectric effects of white light, beads and fluorescent dyes. White light passed as laser beam will be the major source of illumination to be used in the experiment. Laser beam is made of white light that contains light with different colors, wavelengths and frequencies. Applying the concept of photoelectric effect, only light of specific wavelength and frequencies is capable of radiating the surface of a suitable material to emit electrons. Therefore, the study would rely on separation of red and blue lights due to their difference in wavelengths and strengths. The red lights with longer wavelengths directed to the specimen using a mirror is seen to be bright and provides enough light to differentiate between various parts of the specimen (Trusov et al., 2009). Proper illumination is therefore an important factor in this set-up: red lights with maximum brightness and longer wavelengths must be used. This type of light is low in energy compared to the blue light with shorter wavelengths. As a result, it is only suitable for illumination and not proton transmission. The light from the specimen is directed to the emission cube where it is separated from the blue light transmitted by a different mirror. The approach would utilize a combination of fluorescent separation of light and transmission techniques. Therefore, there is a need to use suitable apparatus that would provide the expected results. Blue incident light is good sources of light and hence it will be used to provide both red and blue light.

4.3.Approaching

Engineering designs may have varied approaches depending on the complexity of the proposed projects and the general aim of the research. The proposed design herein would apply a different approach from the ancient microscopy that is known to be large and complicated in their designs. The main aim of the modern microscopy is to reduce the size of the design while increasing other factors such as resolution and clarity among cells being studied. Therefore, the approach for the study is based on the right choice of lights and colors to be used. Having the relevant knowledge on the behavior of every color of light, it is important to note that choosing the right color of light is a major factor for the successful completion of the design. On the other hand, using a suitable dye that would enhance visibility during observation of cells within the specimen is another factor to ensure successful experience with the proposed approach (Laifangbam et al., 2009). The concept idea would then be complemented by an applied solution using a wide variety of research mixed techniques. The approach would entail an application of knowledge for quantum mechanics, electrical engineering, cell physiology, and biomedical techniques.

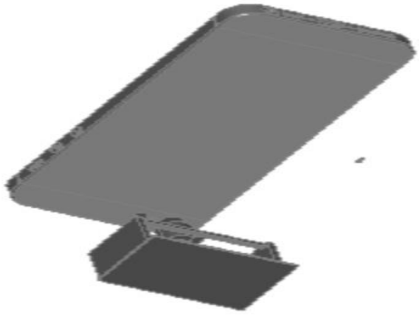
In order to successfully transfer separate lights into the camera lenses attached in a Smartphone, basic photographic skills are necessary for this approach. The success of the design is dependent on the light to be used. Blue incident light used are a good source due to the ability to control the amount and color of light hence, validating the approach as far as illumination process is concerned. However, the approach would entail controlling the amount of red light hitting the specimen via a mirror. The light should not be too much to affect the internal structures or visibility of the specimen. On the other hand, during the transmission process, it is essential to guarantee safe light separation techniques (Litorowicz, 2006). With the information in mind, the approach is designed in such a way that the two mirrors to be used will be mounted at a specific angle and would be of specific size. The size of the mirrors and the angle of inclination are one way of regulating amount of light illuminating the specimen. The basic concept and probably the most important factor to consider in the design of the modern fluorescent microscope, is the ability to regulate light and separation techniques to ensure only dim light reaches the camera lenses for observation.

4.4.Results/Analysis

Image 1: Initial View

The results obtained represents various views of a Smartphone fixed with the designed fluorescent microscope. One important finding in this study was the required arrangement of the setup, which should be done in a specific manner to ensure maximum transmission of light to the specimen. Photography is one of the fields where this modern microscope finds its application. The above diagram shows the initial view of the design. From the appearance, it is clear that the set of lenses is portable and compatible with the Smartphone. The fluorescent microscope is designed to slide below the phone camera to enhance visibility and resolution during photography. The underlying idea behind this design is based on light transmission from two different mirrors directed to a specimen and back to photoreceptors. Light reflected back to the photoreceptors are separated using the fluorescent light separation technique to differentiate between bright and dim light. The dim light is then directed to the camera lenses for viewing. The images formed by this type of camera seemed to be clear and of high quality due to high-resolution power of the fluorescent lenses used in designing the microscope. The above initial view of the microscope is in 3D, showing all the basic concepts behind its fixing and compatibility with the phone. From the diagram, it is apparent that the gadget is designed with necessary universal plugs and clips to provide grips around the phone's camera. The plugs are compatible with most gadgets, making the fluorescent microscope convenient to use over other types of microscopes.

Image 2: Front View

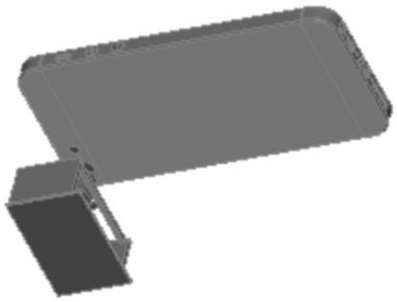


The image 2 is a representation of a front view of the design fixed into the Smartphone. A close examination of the image shows the concept used in fixing the two sets of gadgets. Smartphone is normally designed to have internal cameras with varied megapixels, which have nowadays proved to be producing more quality photos than some of the actual cameras. The lenses fixed in such phones are small but with high resolution powers. Fluorescent microscopy is the basic concept being used by phone companies to enhance their phone cameras. However, the designed microscope, as seen the in the diagram is fixed on top of the phone camera to improve the quality of view and imaging. The gadget's lenses contain two sets of lighting systems, that is, the red and the blue lights. The front view of the design shows that it is operating directly with the specimen and transmitting the magnified images to the phone's

internal lenses. The main reason for this is that the fluorescent lenses used are capable of transmitting brighter light with long wavelengths to capture object from a distance. In the interior layout of the device, there are the photoreceptors directing dim light to the eye-lenses fixed into the phone's objective lenses.

The front view of the design also reveals that it is rotatable about the point of fix on the phone's camera. This property implies that the lenses can be adjusted through rotation to capture a wide array of images from different angeles. Unlike other microscopes whose objective lenses may only be rotated to enhance the view of the obejcts, the lenses in the fluorescent microscope can be rotated to achieve capturing of images at 360 degree. Such lenses have the capability of capturing images from all angles and heights. Due to the application of light of longer wavelenths as the objective lights, Smartphones fixed with these modern microscopes are able to take photos of specimen from a distance while mainting the qulaity and clarity of the photo. Coluration system and concept used in the device also ensure a real presentation of the specimen. The front view of the device shows its actual horizontal height, which may have a different perception with other views. The view presents the device as being a bit longer, implying its internal adjustable system. In other words, it is designed to be adjsuted to meet the size of the every device being used. Not all phones have the same size, and hence, the physical size of the gadget is adjsutbale.

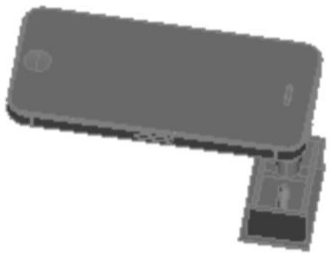
Image 3: Left View



The left view of the fluorescent microscope shows its actual thickness, which is almost twice of the Smartphone. In addition, the view still shows the ability of the device to rotate about the phone camera's objective lenses. The main purpose of the fluorescent microscopy in photography is to magnify images while maintaining the quality. This enables photographers to take photos regardless of the distance between the camera and the object. Evidently, photos taken by Smartphone fixed with fluorescent microscope have been found to be of a higher quality than those taken by cameras with ancient microscopy systems. The technique of fluorescent microscopy can be further improved to reduce the size of the device in such a way that it would be fixed as an internal camera lens for Smartphone.

Image 4: Bottom View

Image 5: Top View



4.4.1. The Smartphone Design – Inner View

In order to perform fluorescent functions, filters are essential optical components. The device's blue filter filters red light from the source. While a blue light emitting diode (LED) or blue laser diode (LD) is used as light sources, the spontaneous emission spectrum is accompanied by a limited amount of red light due to the long tail. Because of the poor signal of the filters, this tiny red light can greatly decrease the fluorescence effect intensity, so that the fluorescence microscopic feature is accomplished. The blue filter is placed at the bottom framework to pass by the filter, before the sample is entered on the slide glass. The upper body of the system after the light enters the sample is located on a red filter and a violet interference filter (Edmund Optics # 52–528)10. The red filter enables the light to pass over 600 nm wavelengths. The blue light from its source stimulates and transforms the fluorescent material into red light. It goes through the red filter and gets to the mobile image sensor. Red filters eliminate the blue light which is not communicating with the fluorescent material. It's like noise, otherwise. The combination of both red filters increases the extinction ratio and thus the signal-to-noise ratio decreases. The mechanical structure overall is very easy and convenient. It has a top and a bottom body.

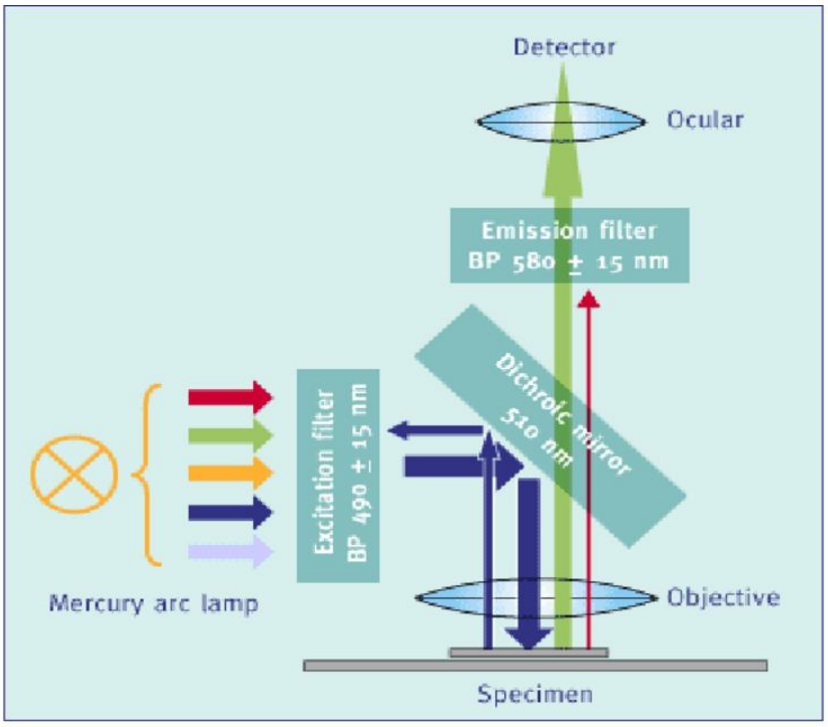
A lens module and a lighting module are available for each unit. A diaphragm or a sample stage is placed between the two by a side hole like a hemocytometer. The two central bodies are connected with torches. The Smartphone can move over the upper body until the external lens module is aligned with the camera. Unless the phone has a rubber shell, ample friction is quickly retained after deciding the correct location. Any kind of Smartphone will therefore suit this mechanical structure.

Another important step that I believe have benefited many electronics companies dealing with cameras and smart phones is the application of photographic technology. Smartphone users, in particular, are probably interested in the recreational services offered by companies that make gadgets, such as music and photography. Thus, standard digital cameras are one of the considerations that customers find in

smart phone purchases. The principle of fluorescent microscopy has since been implemented in the production of phone cameras by leading handset manufacturers, such as Samsung, Apple and Oppo. Many of the key reasons for the company's frequent launch of a new Smartphone model include technical development in the fields of sensors, sound systems, battery capacities and software. In particular, each company's efficiency of the phone cameras has improved in different versions. The camera performance is strong because of technologies used in the electrical engineering of fluorescent microscopes that enhance the efficiency of telephone cameras (Hamilton, 2009). These fluorescent microscopy applications are only some of the few applications that I have utilized, but with the technology improving progressively to improve the experience in several areas.

4.5.Application and advantages of Fluorescent Microscopes

Figure 3: Optical Setting for Fluorescent Microscope



The diagram above represents another approach that can be used to set up the apparatus for designing fluorescent microscope. This approach focuses on the best positioning of lighting systems to ensure best results as far as illumination and light transmission is concerned. An example of light sources that can be used for this set up is mercury lamp due to its ability to produce light with a continuous spectrum of wavelengths (Rigler & Elson, 2012). Among the blue incident light from the mercury lamp, only the red light is capable of providing perfect illumination of specimen. Therefore, the dichroic mirror is used to direct the red light to the objective lens after passing the filter. The main purpose of the dichroic mirror is to allow for deflection of the light from the mercury lamp while transmitting only the red light

with suitable brightness and wavelength for illumination of the specimen. During the microscopy, the specimen under observation is marked with fluorescent dyes for before being situated in the microscope. A phenomenon known as stoke shift is normally associated with the entire microscopy process. The phenomenon involves a single photon from a light source transmitted to hit the specimen. The photon transmitted from the light source is capable of releasing energy that is used to excite the specimen release an electron. The exited electron losses energy in the process and hence releasing a photon with longer wavelength than the initial one. In most cases, the source of light to provide energy for excitation is laser beam, which is capable of producing light with different wavelengths.

Based on the analysis of qualitative data collected on the use of the modern fluorescent microscopes, it has a wide range of application in different industries and fields. However, the new versions are portable hence, increasing the convenience of use during complex cell analysis and medical diagnosis of diseases (Hammes & Egli, 2010). The most obvious advantages of the microscopes over others include compatibility with other devices, high resolution, and affordability. The device was found to be applied in various fields such as photography, biomedical and medicine fields. In photography, the device is fixed with camera lenses to enhance imaging and clear capturing of objects (Becker, 2012). This is possible because fluorescent microscopes are small and can be fixed into portable gadgets such as cameras and Smartphone. With their high resolutions, the microscopes fixed in these gadgets are capable of achieving clear magnification of objects hence producing high quality images during photography. The microscopes are also used in the study of cells in medicine to determine close molecules within cells (Kim et al., 2015). Due to the high ability to distinguish between close structures, the modern microscopes have been used in hospitals to improve diagnosis of diseases and defective cells among human beings. Study of cells involves analysis of foreign bodies that may assume the form and structure of the cells. Such foreign bodies may only be identified using microscopes with high resolutions hence, making modern fluorescent microscope one of the best for this purpose.

5. The Working Concept for a Fluorescent Microscope

Fluorescent microscopes are capable of taking magnified images with high qualities compared to the traditional microscopes. The underlying lighting principle used in this design is a fluorophore, which is a substance capable of emitting light of varied wavelengths. As a consequence, a researcher may vary between various specimens under study. The different lights with varied wavelengths emitted by the fluorophore are assigned to specimens under investigation, implying that every object under study is assigned a unique color code. Clarity of images in the fluorescent microscope is due to the ability of the

objective lenses to transmit red light of long wavelengths and less energy. The excitation energy transmitted is used to trigger photons to discharge discrete amounts of energy required in the imaging process. Light with long wavelengths transmitted to the specimen by the objective lens is bright but low in energy to provide enough illumination while annulling heating effects to the specimen (Hilderbrand & Weissleder, 2010). Besides, the fluorescent microscopes are designed to differentiate between blue and red lights during transmission. As a result, only red light is transmitted to the specimen due to their brightness while blue lights are transmitted to the eye lenses for viewing due to their dim properties.

The key explanation for fluorescence microscopy is that specific cells and other elements inside the observed cells are separately identified. The process of identifying these cellular components is possible through optical microscopy. This is the main concept applied in cell biology and other studies involving examination of intracellular substances. Arguably, cell of living organisms is microscopic and close packed together, thereby causing confusion among scientists during cell analysis. Fluorescent microscopy should therefore be used to help to identify close cells because of the high-resolution powers of this microscope system. The concept has also assisted in the diagnosis of diseases such as cancer during early stages (Lee et al., 2012). Cancerous cells, before starting to grow, may assume similar shape and form as normal body cells. Such cells can only be identified through fluorescent microscopy. This modern microscopy has advantages such as identification of cellular components by making use of fluorescent substances. In addition, it is vital in tracing the exact location of chemicals of life such as protein in a given cell (Müller, Schumann & Kraegeloh, 2012). The introduction of the modern fluorescent microscopes has improved the identification of cells, proteins and other molecules (Wang et al., 2010). Lastly, the microscopy is important in providing clear visuals of patterns showing the effects of fluorescent substances on body cells.

5.1.Cost

The research requirements include LED lights capable of producing blue incident lights, which is estimated to be about $50. The cost of other apparatus includes $20 for lasers, $10 for excitation filter, $10 for emission filter, 2 dichroic mirrors at $30, and a blue light detector at $60. The total cost of these apparatus is approximated to be $180.

Table 1: Cost of the set up

Apparatus	Approximated Cost
Led Lights	$50
Lasers	$20

Excitation filters	$10
Emission filters	$10
2 dichroic mirrors	$30
Blue light detector	$60
Total Approximated Cost	**$180**

Similar operations normally require some capital to ensure that they are completed successfully. The capital requirement is designed to deal with different problems such as equipment purchase and the maintenance of general project logistics. Compared with other ventures that require the replacement of old fluorescent microscopes, the cost will be smaller. In other words, designing modern fluorescent microscopes attracts less cost compared to other types of microscopes. The actual cost of fluorescent microscope similar to the one in the above images may differ from one company to another. However, the gadget may averagely cost about $180, which is lower than the cost of traditional microscopes. The low cost is due to factors such as portability and a wide range of application of modern technology aimed at cutting the entire cost that would be needed for other types of microscopes. It is fair to say that the provision of necessary materials such as dyes, mirrors and beads is manageable and requires little investment in capital. The tools needed to complete the project can only be given with basic feedback at reduced costs. The low design cost for modern fluorescent microscopes is one of the biggest advantages. There is a need for significant capital inputs for certain types of microscopes which may delay certain activities during the design process. However, only a good command of modern technology for electric engineering is needed for designing a simple fluorescent microscope as the main input together with few affordable devices. The low cost of the proposed design offers several advantages.

Contrary to other complicated designs, the modern fluorescent microscope will require much of designer activities such as displaying complex specimen structures. For example, the design allowed for the actual counting of cells and molecules within specimens, thereby enhancing productivity. The low cost of the study is also based on the nature of the fluorescent microscopes, which is its ability to incorporate a wide variety of disciplines. This is a major consideration since the design would be comfortable handled by individuals from different fields of study, unlike other designs that may only require complex electrical engineering skills (Sengoz & Isikyakar, 2008). The entire design made use of different skills from fields such as engineering, medicine, photography and physics. The physical techniques such as a clear understanding of light transmission were a major resource during the set up. The properties of different mirrors when it comes to reflection of light and the right arrangements were a

major factor during the arrangement of the apparatus. Another important skill that was necessary in cutting the cost of the entire setup as the medical techniques such as cell physiological processes and the general understanding of human cell structures (Marcu, 2012). The researchers would have inquired extra cost if they would not be able to carry out the actual counting of cells within the specimen. This would mean spending some good capital on hiring experts for the process. Arguably, designing modern fluorescent microscopes requires a small capital input than other types of microscopes. The main idea behind the design of the modern fluorescent microscopes is to reduce size and cost of the device, which is achievable through using less apparatus that are affordable and integrating techniques from a wide range of disciplines.

6. Conclusion

The field of electric engineering is science which focuses on the design of various models and devices. The paper focuses on the procedures and techniques needed to create the Handheld Fluorescent Smartphone Microscope (HSFM). In the engineering field, the HSFM can have different applications. However, the main function of the HSFM in this report is the development of microscopes, using the underlying concepts of bio-detectors as a blue light detector. The system has a broad variety of uses, and it is typically installed directly on cameras of portable devices, such as cell phones. One of the greatest successes owing to its performance and ease of usage is the use of fluorescent microscopes in the biomedical field. Compared with other microscopes, the device is also cost effective and quick, making it the most effective option during complicated cell analysis. The older version of fluorescent microscopes only varies in size and plays the same role as the later versions. In terms of portability, the older versions are large and uncomfortable. It is possible that every electronic device’s applicability depends on different factors like costs, efficiency, portability and other device compatibility. Microscopy use in biomedical and medicinal areas has in the past few years been quite complicated owing to some drawbacks in the sense of old microscopes. The role of microscopes in cell imagery and scans, however, is one benefit that has really been helpful in various medical studies. In contrast to the traditional microscopes, modern fluorescents with high precision and sensitivity microscopes have increased clinical experience. As a well described vision of the inner tissues, cells and molecules of the conventional microscopes, medicines consider it simple, without misunderstanding to diagnose many infectious cells. Scientists strive to build instruments for direct cell biology by way of microscopy that has vastly increased fluorescent light microscopy production and advancement over years.

Furthermore, the lenses were highly resolute so that the researchers could clearly separate close cells when observing them. The expense of the entire project could be managed, which improved certain tasks such as real counts of cells, tissues and tumors and the monitoring of fluorescently-tagged genes. The findings of this research show the value of fluorescent microscopy in several specific areas. This ensures that a broad variety of areas, including molecular and cell biology, environmental management, healthcare and food processing may refer to the principle of fluorescent microscopy. Fluorescent microscopy's remarkable role in the field of biomedicine includes detection and follow-up of cells, proteins and other molecules in order to identify defective cells.

The fluorescence concept clearly resembles its light separation by using different optical filters. Electrical engineers regard the quality and the brightness of the pictures as their principal consideration when constructing microscopes. To achieve this, integrated technologies must be applied in order to understand all of the techniques necessary to complete a modern microscope design. Fixing essential microscopy problems, such as optical diffraction and low image contrast, involves steady developments in the area of microscopy. The optic principles such as lightening angles, processing methods and definitions employed in the study of photographs also need to be specifically understood.

7. Recommendations

The real expense of fluorescent microscopes similar to that in the photos above can vary from company to business. When shopping for the product to increase the experience, there are several factors to consider. First, the acquisition of the device for correct functions is important. People can buy the gadget for quality photos and videos on their Smartphone. The reputation of the company that offers services is another factor to consider when making purchases of the gadget. In the production of electronic products, various firms include a variety of technology. It is also necessary to purchase the commodity from a reputable quality firm. It is also a smart step to ensure different sections of the fluorescent microscope and to make sure that the required spares are obtained in the event of injury. Setting up devices is often a challenge which can lead to user losses. The consumers will then ensure that they have the information they need regarding the usage of the apps. Proper training on the use of fluorescent microscopes is a good step towards better results.

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