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A novel all-optical video imaging and transmission system using optical fibre

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ABSTRACT : Fibre Optic imaging systems are fast emerging in diverse applications areas like endoscopy, machine inspection, video transmission, etc. We propose and develop here, for the first time, motion picture sensing using fibre optic imaging. Piezo-aided vibrations of an optic fibre cable has been successfully incorporated in the design, to scan and transmit optical data. Refinement and signal processing done on these optical signals allows us to analyze and confirm that this mechanism is suitable for continuous digital data transmission. In this paper we introduce some of these aspects and explore their realization in micro-opto-electro mechanical systems. Preliminary results of the proposed structure have been summarized in this paper.

Keywords : Imaging, Fibre Optics, All-optical, Video, Piezo transducer

I. INTRODUCTION

Early television camera tubes invariably used photoemitters as light detectors. Photoelectron emission formed the image [1]. The image dissectors, however, suffered from a range of drawbacks, primarily due to their dependence on high light levels. The next camera tubes to evolve were the storage types that employed the transparent conductors. The vidicon tube employing antimony trisulfide as the photoconductor was the first successful photoconductive television camera tube. Various other photoconductive camera tubes have been developed since, all identified with a different trade name. All these tubes operate with a target readout signal and use low-velocity scanning with an electron beam. The deflection and focusing of the electron beam vary in many of these different tubes. Most tubes utilize magnetic focusing and magnetic deflection. The rest employ electrostatic focus and magnetic deflection, or magnetic focus and electrostatic deflection, and a few use electrostatic focus and deflection. All use an electron gun for generating the electron beam, derived from a thermionic cathode that emerges from a small aperture.

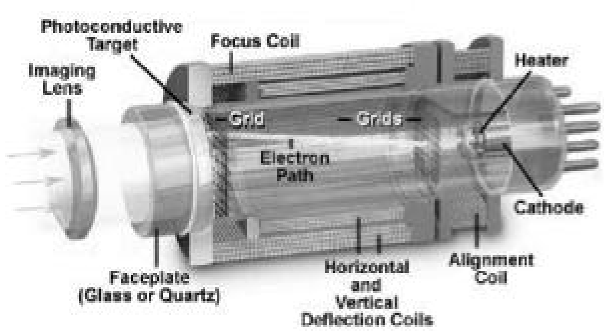

Fig. 1 : The vidicon TV camera scanning system, which employs an electron beam to scan the entire image.

A schematic depicted in Fig 1 shows the basic principle behind such an architecture, where the object to be scanned or televised is focused on a transparent conductor, usually coated with photo resistive materials like Antimony Trisulfide, Selenide, through a convex lens with the image being formed at its focus. Depending on the varying intensity of the image formed on the screen due to the object at infinity, the photo resistive material develops variable conductivities on its areas depending on the intensity of the exposure due to the object. A beam of electron scans the screen, the pattern of which is repeated on the raster screen through synchronization pulses transmitted during the fly back time of the electron beam. Depending on the variable resistance encountered by the electron beam, a current flows through the load resistance and the optical information is stored in the form of electrical signals. Due to several bulky electro-mechanical structures involved, these technologies are **cumbersome.**

To eliminate the mentioned bulky structures, the technological developments for fabricating and manufacturing solid-state imaging arrays [2,3] was started 20 years ago. The technological advancements and developments in thin film processes have spurred the development of solid state cameras and thin film single unit sensors which perform at par with the present camera tubes, but the cost of manufacture and the complexity is not sustainable. Consequently the possibility of developing newer and yet more advanced alternatives is constantly being looked into.

This paper reports a **novel** piezo-vibration synchronized motion picture sensing methodology using optical fibre [4,5]. Fibre optic cable embedded [6] within a piezo-electric crystal can be employed to serve as a micro-structured single unit device for **real-time** motion picture sensing and transmission. Optical signal transmission of continuous phenomena can be achieved through synchronized or tuned vibration of the free end of the fibre optic wave guide. The free end of the optical fibre or the scanning probe is vibrated at a frequency required for generating the appropriate frame rates for real-time **streaming video** applications. This approach eliminates the incorporation of complex electron emission sources. deflection fields and associated circuitry.

II. STRUCTURE AND METHOD

In our system, information sensing at the transmitting end is done through tuned and synchronized vibrations of the tip of an optic fibre cable that scans the entire area of interest. The particular image to be scanned is focused to a small area through a powerful lens on a screen. A schematic of the proposed design is shown in Fig 2.

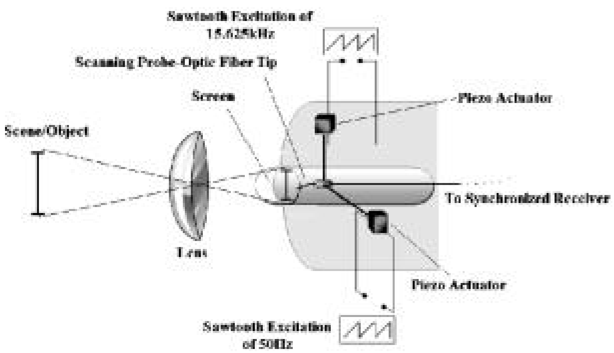

Fig. 2 : A schematic of the motion sensing transmitting unit for real time data transmission.

The tip of the fibre is continuously translated by application of a periodic linear movement. Two translation sources are required for movement in the two directions, one with the frequency 15.625 kHz and another sawtooth signal of 50Hz. These two synchronized signals are generated through a Microcontroller and fed to an amplifier through a Digital to Analog converter which drives a piezoelectric crystal. The fibre tip is attached to the piezo crystal. This allows the fibre to continuously scan the screen, precisely transmitting information, at a frame rate of 25 fps. The screen pixel resolution is 625 × 625. For reconstruction at the receiving end, a similar process is used, wherein the disturbances are tuned and **synchronized** to those present at the transmitting end so that at the receiving end too the tip of the cable continuously vibrates creating the impression of continuous motion picture. The proposed principle was verified for preliminary results and analyzed through a prototype developed by us. Amplification and re-generation of the transmitted optical signals is a great challenge when considering longer distances. Under such circumstances repeaters or pre amplifiers would be necessary.

III. DESIGN OF SYNCHRONIZED VIBRATION GENERATOR

The implementation of the vibration unit required that the synchronized signals be generated through an 8051 microcontroller interfaced to a DAC0800 8 bit Digital to Analog converter controller. The analog signals generated were **sawtooth** signals of frequencies 50Hz and 15.625 kHz. These signals were boosted by an audio class amplifier to 10 Vp-p to drive the piezoelectric transducer. We implemented an LM386 audio amplifier of 20 dB gain for signal amplification. The ratings of the piezo elements used (from Piezosystem Jena) was 10Vp-p, 6 mA. Fig 3 shows the schematic of the circuit used. For generating the vibrations in the two orthogonal directions, vertical and horizontal, two piezo transducers of same rating were used.

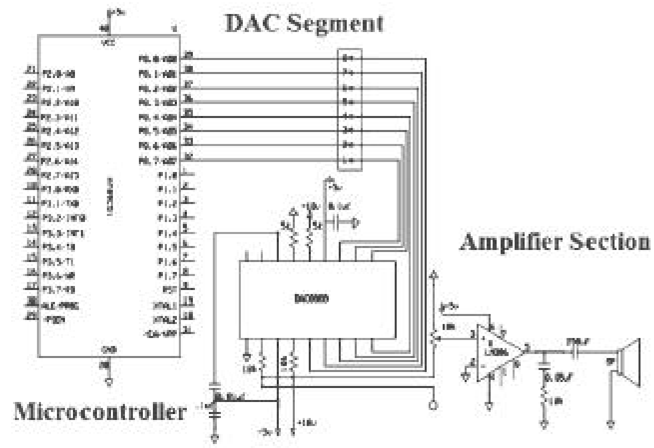

Fig. 3 : The circuit implementation of the synchronized vibration generator.

The two vibrating elements were mounted at perpendicular orientations in order to give the required motion of the optic fibre probe. A multimode 1000 μm diameter glass fibre was incorporated in the structure for the purpose.

IV. RESULT AND DISCUSSION

Real-time data scanning and transmission has been realized through controlled and synchronized vibrations of the free end of an optic fibre cable. The frame rate was 25 fps. The preliminary test for the verification of the principle has been summarized. The transmitted optical information must be processed at the receiving end, as shown in Fig 4, for synthesizing the picture information contained in the signals. There are multiple ways in which this can be done. For testing the design parameters an example image source having three basic colours red, blue and yellow was transmitted. The image is shown in Fig. 5.

The free end of the transmitting end was vibrated synchronously as explained in the previous sections. At the receiving end, the motion of the free end of the receiving end was captured using a digital camcorder and the entire motion history of the free end thus obtained was split up into individual frames, as shown in Fig. 5, using the software Studio Manager™ from the company DVDVideoSoft [7].

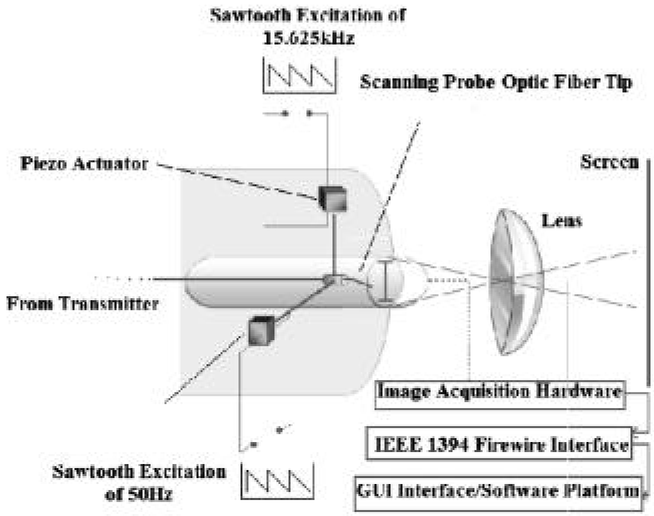

Fig. 4 : The receiving unit for signal refinement and image processing.

The frames were analyzed at every instant for judging the position of the portion of the image being transmitted and obtaining the required colour information for further signal processing. The continuum of the frames was analyzed for parity between the image transmitted and that obtained at the receiving end. Strong parity confirmed our capability of real-time capturing of the optical information at the receiving end. The resultant image is magnified by a projecting lens combination on a screen.

For closer analysis the continuous video was split into individual frames as shown in Fig. 5. As we analyzed the individual frames we notice that at every instant the colour information received is in synchronisation with that of the transmitted image. We also notice that the free end of the fibre does undergo vibrations in the two planes x and y. The maximum displacement obtained in the two domains was 2 mm and 4 mm respectively. All through the consecutive frames it was seen that the formed image nearly agrees with the transmitted version.

If the original image is analyzed pixel by pixel and compared with the received version it can be seen that colour information is reproduced to a reasonable degree. The accuracy can be improved by shielding the system from external vibrations and from the interference due to the natural vibration frequencies of the structure.

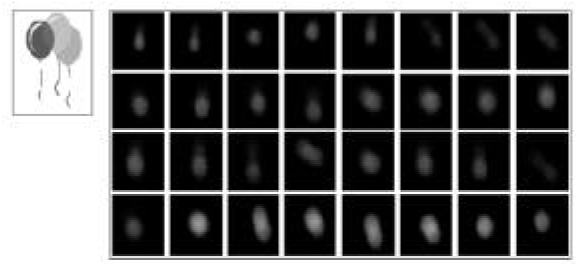

Fig. 5 : The transmitted image and the successive colour frames of the entire motion pattern.

V. CONCLUSION

Preliminary results of the tuned vibration image acquisition and real-time data transmission system are given. The results were obtained by incorporating a 1000 µm multimode optic fibre in a dual mode synchronized vibrating system. We have verified the proposed principle using a simple approach. The image acquired in this principle can be further processed to reduce error. The approach is rather basic and comparatively The simplicity lies in the concept itself and the fact that no expensive solid state devices have been employed. When considering the miniaturization of the proposed architecture, MOEMS (micro-opto-electromechanical systems) level fabrication must be considered for embedding the fibre within a piezo-electric crystal assembly capable of undergoing dual mode vibration as elucidated in the principle. The scanned information could be stored as electrical signals through required associated circuitry which can be easily scaled down to feasible limits. These areas are yet to be dealt with, for realization of proposed design at ultra small dimensions.

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