EVALUATION OF BLADES BY OPTICAL COMPUTING

by

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SUMMARY

A simple, inexpensive and rapid technique to assess the sharpness of scalpel blades by laser diffraction is presented. Two of the factors contributing to the edge sharpness are the cutting angle and grinding finish of the side faces terminating into the edge of the blade. The method has been utilized to evaluate the grinding finish of the side faces by spatial spectrum analysis in the reflection mode, while the cutting angle has been determined by laser diffraction from the blade edge. It is therefore possible to evaluate an optimum set of values for the above two factors which in turn could lead to production of sharper blades.

1. INTRODUCTION

1.1 Non contact measurement has had an explosive growth in the last few years on account of the capabilities of laser and related electro-optical techniques. (1,2). This growth in optical computing techniques (also called optical transform, Fourier transform, laser diffraction) has resulted in solving as wide ranging problems as imagery analysis, biological cell characterization to industrial measurement. (3). Optical computing techniques are also being applied to the precise measurement of the dimensions of wires, fibres, spheres etc; identification of defects in metal, plastic, papers, etc.; and the counting and classification of particles. (4,5).

1.2 In this article an attempt has been made to make use of the optical computing technique for the evaluation of scalpel blades. At present, inspection is mainly visual by trained inspectors who may use magnifiers, microscopes or projectors to assist them. The proposed method is a detailed laboratory analysis. It is based on a process of intensity Fourier transforms whereby measurements are made on the spatial frequency spectrum of the object under test rather than on the image of the object itself. The technique has several advantages over other methods using conventional instruments, which rely on production of a high quality image of the object. The accuracy of an image-forming instrument is limited by any factors which degrade the sharpness of the edges in the images, such as aberration in the imaging lens, vibration of the object and air turbulence.

2. THEORY

2.1 The working principle behind optical computers is the technique of "Diffraction Pattern Analysis". The diffraction pattern of an object is its signature. If white light is used, there would be an overlayed multiplicity of different coloured patterns of different size describing the same object. Since the laser is of single wave length, there is only one pattern. The object and its far field diffraction pattern have a Fourier transform relationship to each other. If the object distribution is represented by $f(x,y)$, its Fourier transform $F(u,v)$ is given by:

$$F(u,v) = \iint f(x,y)e^{-i2\pi(xu + yv)}dxdy$$

where u and v are spatial frequency variables.

2.2 This optical realisation of the process of Fourier analysis is based on the following concept. A two dimensional pattern of light, whether or not it has a periodic structure, can be analysed into or synthesized from a series of periodic sinusoidal light patterns of various spatial frequencies (cycle/mm) of differing amplitudes arranged in two dimensions. The spatial frequency is represented as the intensity distribution in the image space and denoted as a function of spatial co-ordinates in the image plane. The parameter "time" used in Electrical Engineering is translated as "space" when used in optical processing. The distribution of light in the optical transform plane represents the distribution of amplitudes in the spatial frequency spectrum of the original pattern, the spatial frequency being displayed radially from a central origin at zero cycles/mm.

2.3 The blades are characterised in terms of the sharpness of their edges. If a collimated laser beam is diffracted off a blade edge, its diffraction pattern is obtained in the image plane. The diffraction pattern consists of blips and nulls of intensities. The analysis of the diffracted energy leads to the measurement of edge information. This aspect is further discussed in section 4.1.

It was found that the cutting angle and the surface finish of the side faces terminating into an edge are the most important parameters in defining sharpness. Evaluation of these parameters has been carried out and is presented here. Incorporation of an appropriate set of values for the above two factors, besides the material, could lead to production of blades with sharper edges.

3. EXPERIMENTAL

The system used consists of a one milliwatt Helium-Neon laser, a spatial pin hole assembly (PA), a collimating lens (CL), a Fourier transforming lens (FTL) and a detector system - arranged on an optical bench as shown in Figure 1. Initially, the collimation of the illuminating beam is ensured by a Standard Plane parallel Shear Interferometric method as shown in Figure 2. Further, it is necessary to see that the Fourier transforms so produced are insensitive to object translation. For this, the Fourier plane P_2 is located with the help of a speckle interference pattern obtained on a ground glass plate. The setup for the location of plane P_2 is shown in Figure 3. If an object is placed in plane P_1 (front focal plane of F.T. lens) we obtain its Fourier transform in plane P_2 (back focal plane of F.T. lens). Thus the Fourier spectrum analyser is aligned and ready for further experiments.

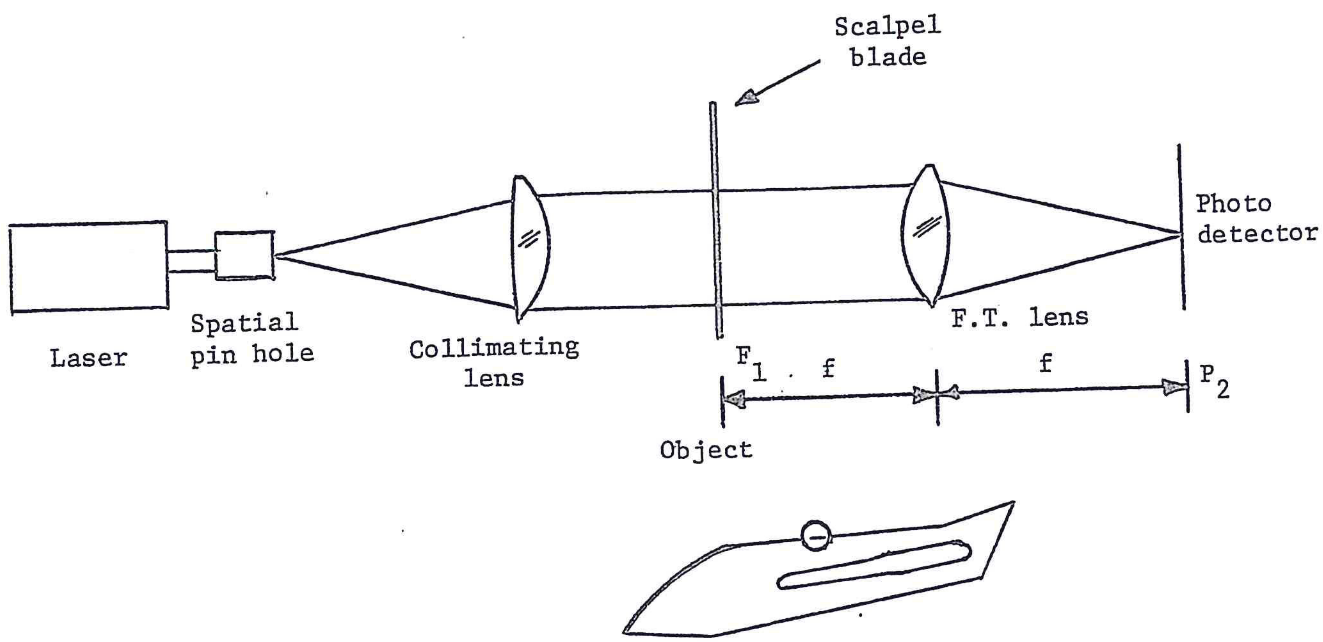

FIGURE 1: FOURIER TRANSFORM ANALYSIS

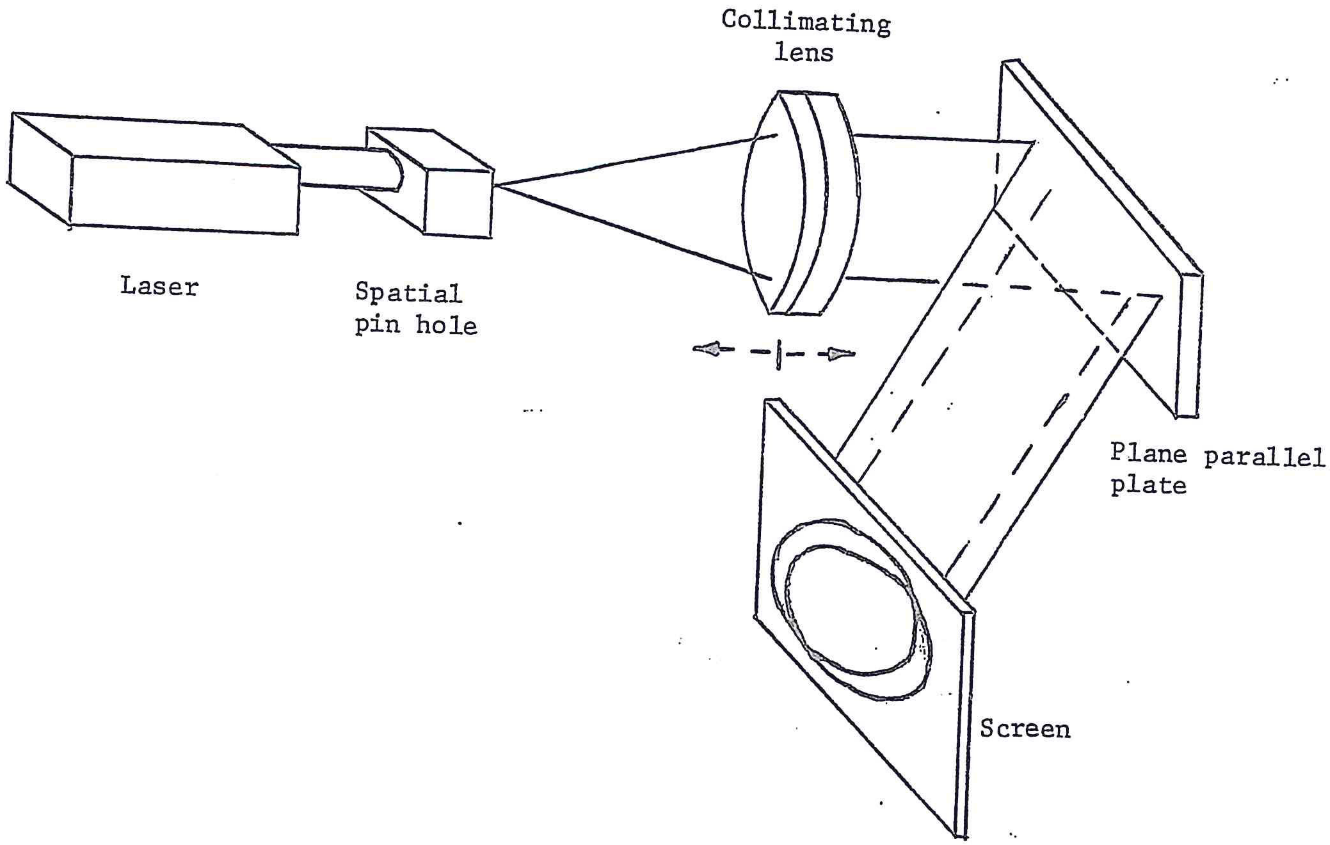

FIGURE 2: PLANE PARALLEL PLATE SHEAR INTERFEROMETER FOR INITIAL COLLIMATION

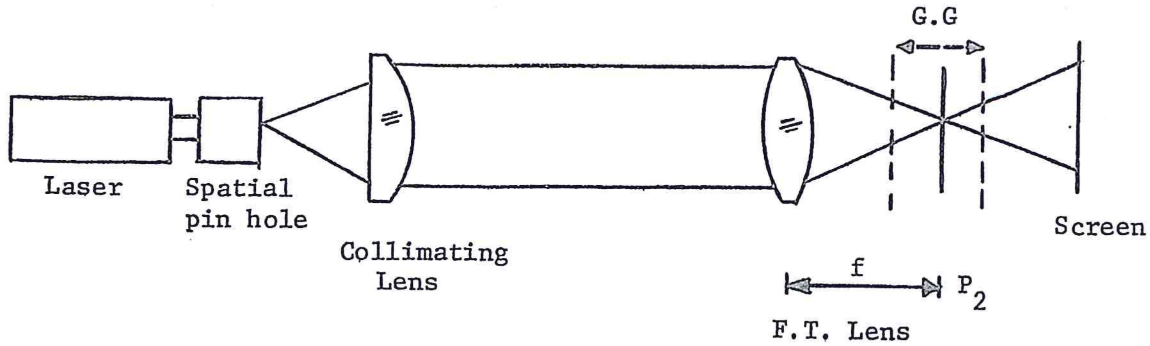

FIGURE 3: LOCATION OF PLANE P_2 BY SPECKLE PATTERN

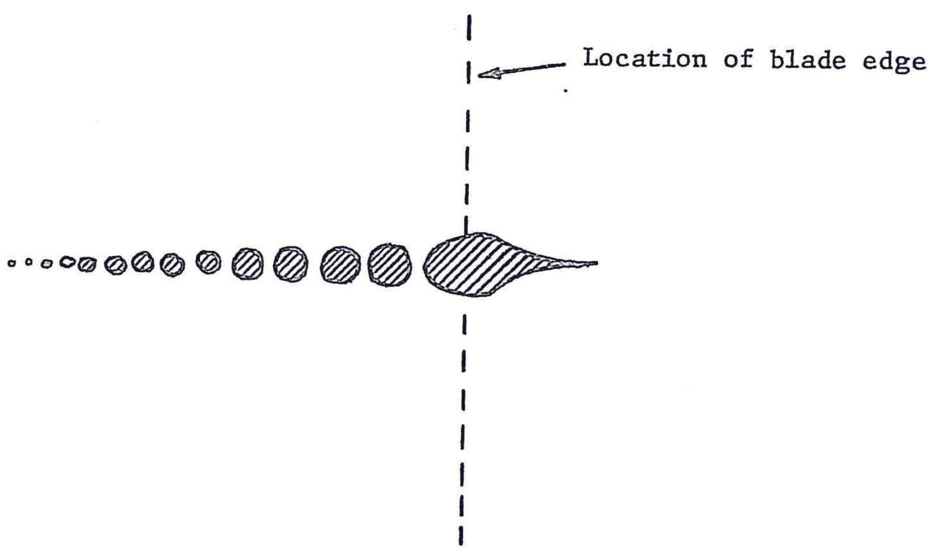

FIGURE 4: A TYPICAL DIFFRACTION SPECTRUM OF A SCALPEL BLADE EDGE

4. RESULTS AND DISCUSSIONS

4.1 A typical Fourier transform spectrum of a scalpel blade edge as observed on the screen is shown in Figure 4.

It is observed that the sharper the edge, the higher is the spatial frequency content, which means that there is a wider coverage of light in the image of the spatially periodic intensity distribution. On wear, the highest frequency reduces, thereby indicating a blunt edge. The intensity fall-off with lobes is measured at various spatial frequencies with the help of photo-detectors. Intensity versus spatial frequency curves for diffraction patterns of perfect, sharp and degraded edges are shown in Figure 5. It is observed that the detector output drops more rapidly with increased spatial frequency for a rough edge compared with a perfect edge. However, the plot of intensity versus spatial frequency, although showing clearly the difference between perfect, sharp and degraded blades, is not ideally suited for a blade manufacturing plant with simultaneous sharpness monitoring facility.

4.2 Figure 6 shows the schematic arrangement for obtaining the Fourier transform (reflection) of the side flanks of the blade which terminate into an edge. Figure 7 shows the reflection Fourier transform of the side surface. In this Fourier spectrum of the side faces of the blade, one observes spatial frequency lobes parallel to the edge of the blade. This could be attributed to the corresponding information present on the side face in the form of a grating like (vertical) structure normal to the edge of the blade. Such a structure formation could be the consequence of surface interaction during the grinding process resulting in erosion wear tracks. The grating like pattern could have been generated on account of uneven machining and gives an indication of the uneven grit size of the grinding wheel and hence its influence on the grinding finish. However, evaluation of grinding processes must take account of the work material, the cutting forces and temperatures, the surface quality of the workpiece, the wear of the wheel and knowledge of the kinematic mechanism of the grinding process. Especially necessary is a knowledge of the grain distribution in the wheel and the kinematic factors of the contact conditions.

The present technique gives a rapid indication of the efficiency of grinding processes where the blips and nulls of diffraction pattern on reflection on account of grating structure could be shown to be different from a pattern free of periodic structure for well ground edges. For well ground blades, the diffraction pattern does

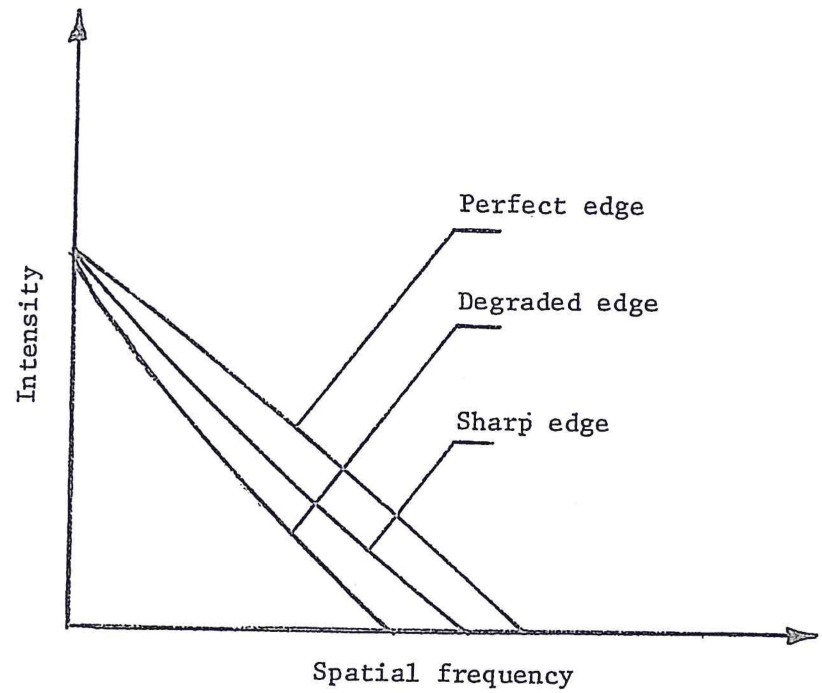

FIGURE 5: RELATION BETWEEN INTENSITY AND SPATIAL FREQUENCY

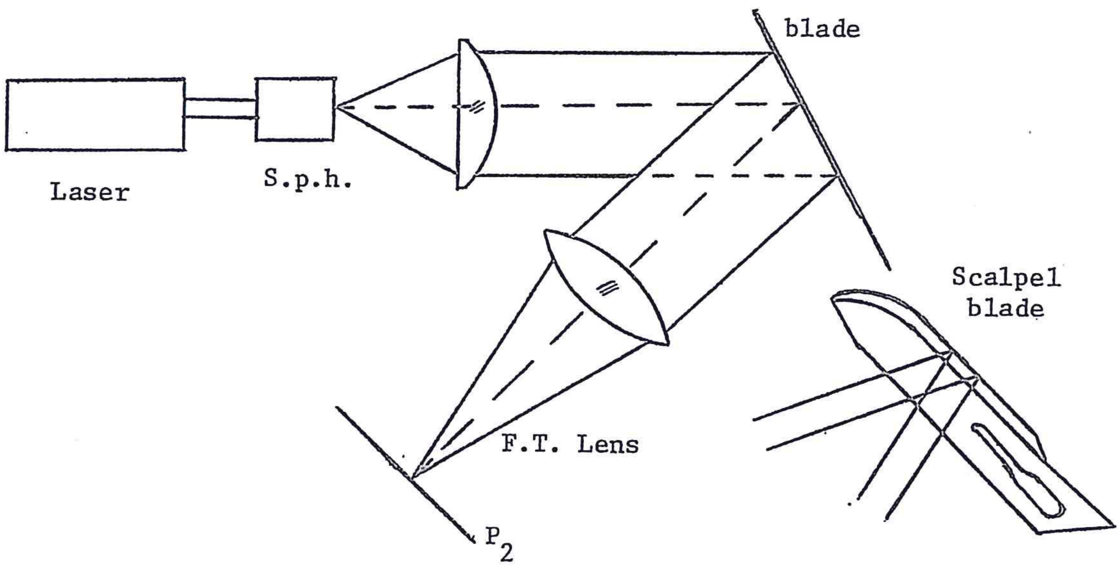

FIGURE 6: SCHEMATIC ARRANGEMENT FOR OBTAINING FOURIER TRANSFORM (REFLECTION) OF THE SIDE FACE OF THE BLADE

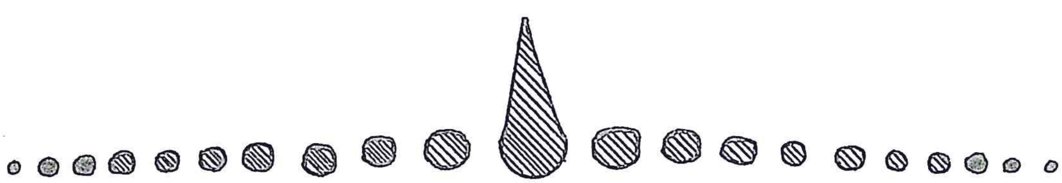

FIGURE 7: REFLECTION F.T. OF THE SIDE SURFACE OF THE BLADE

not indicate any spatial frequency lobes parallel to the blade edge. Presence of any spatial frequency lobe parallel to the edge will give an immediate indication that the edge grinding process had not been efficient.

4.3 For measuring the cutting angle, the edge of the blade is kept along the laser beam as shown in Figure 8. We obtain two diffraction patterns intersecting at an angle ϕ as shown in Figure 9, which is supplementary to the cutting angle $\theta = -\phi$. Measurement of the angle using this technique appears to be quicker compared to conventional methods using image forming optical Instruments. The information so obtained could be utilized to arrive at an optimum system which could lead to manufacture of sharper blades.

5. CONCLUSIONS

The contributing factors for the edge sharpness of a scalpel blade are:

i) grinding finish on the side faces of the blade terminating into an edge.

ii) cutting angle of the edge.

The optical transform technique presented above gives a rapid evaluation of the cutting angle as well as the effectiveness of the grinding process. The information so obtained could be utilized to arrive at a manufacturing system with an in-process sharpness monitoring facility.

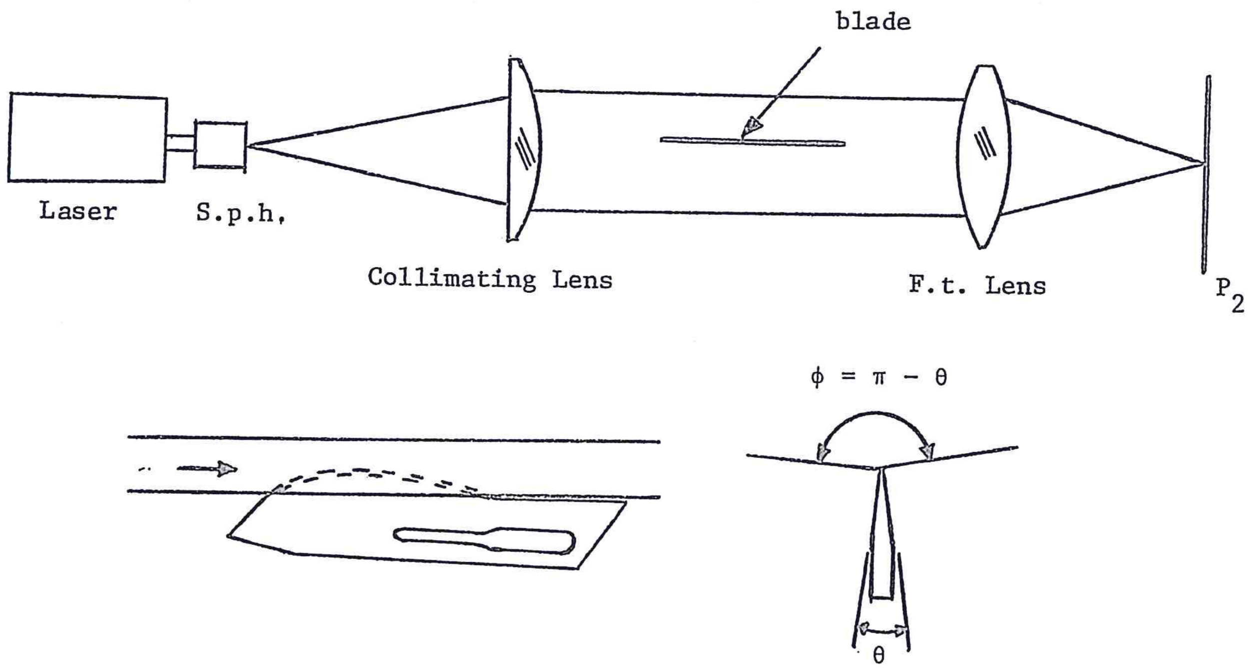

FIGURE 8: BLADE ANGLE MEASUREMENT

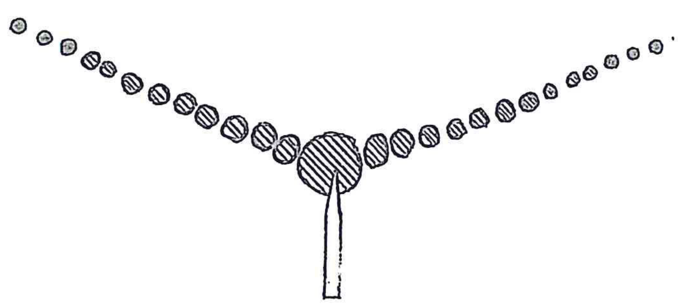

FIGURE 9: DEFFRACTION PATTERN OF THE CUTTING ANGLE

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4. CUTTERRIDGE, O.P.D. "Computer Synthesis of Lumped Linear Networks of Arbitrary Structure" in SKWIRZYNSKI, J.K. and SCANLON, J.O. (Eds.): Network and Signal Theory (Peter Peregrinus, 1973), pp. 105-111.

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