OPTISPEC® Micro Enterprises Inc.
Microscopes - Fiber Optic Inspection - Video Equipment - Super Abrasives
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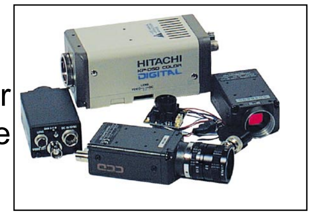
Optical versus Video Primer

A Primer for our Valued Customers



Micro Enterprises has offered Instrumentation and Video Microscopes to the fiber industry for connector inspection on the production floor and laboratory for more than 10 years.

In the past, many of our customers have requested more detailed information and clarification of true magnifications for inspection needs and quality procedures. This is a very valid requirement as the industry continues to grow and our products become more widely used throughout the world. It is becoming essential for the cable and connector manufacturers to be convinced and prepared to document that the inspection process is consistent among vendors and customers.

As Micro Enterprises began to introduce video inspection to the production floor of the fiber cable manufacturing industry in 1988, one of the first questions has always been "What magnification are we using?". The general criteria has always been an optical inspection of at least 200x for single mode fiber.

All of the current documentation and publications detail video or electronic magnification as determined by the primary lens, camera tube or chip size, and the size of the monitor. We have followed the lead and supplied this information as a part of our manuals and documentation with most of our instruments. Unfortunately, this information does not provide the total picture as it relates to the increased demands for higher resolution and defect inspection in the micron range.

These new requirements have prompted us to provide the following information and data to help you make the right decision regarding your inspection needs. We attempted to provide this information in the most basic form to alleviate any additional confusion regarding this subject.

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Optical versus Video Primer *continued*

Microscope Objective Lenses

Objective Lenses are offered in many varieties and formats that are generally specific to the manufacturer's equipment, however there are some standard lenses offered. The numbers and engravings onthe lens casing do provide valuable information. All of the lenses we use are designed for reflected or incident light. (Mainly for surface or materials inspection.) Biological lenses are different in that they are designed to compensate for the thin "cover glass" that is mounted on a biological microscope slide. Biological lenses will always have a 0.17 or something very close, specifying that the objective is corrected for cover glass thickness of 0.17 mm. This only affects the reflected light image on 10x and higher objectives. Biological 4x lenses can be used for reflected light.

Common Lens Case Engravings

LWD	Long Working Distance
ELWD	Extra Long Working Distance
5x/10x/20x/40x/100x	Describes the primary magnification
0.10 / 0.30 / 0.65	Describes the Numerical Aperture of the objective lens or N.A.
M20x	" M": Designates for reflected light
240 / 0	Optical Tube length / 0 (no cover glass correction)
240	Optical Tube length

Objective Lens Definitions

Working Distance:	Distance from the front of the lens to the sample.
Focal Length:	Located behind the objective lens (between the lens and the eye piece or camera). Higher magnification lenses 5x,10x,20x, etc. have a focal length in the range of 3-50 mm. Described as the dis tance from the vertex of the last lens to the focal point.

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Optical Tube Length

The physical distance between the adjacent focal planes of the objective lens and eyepiece or CCD camera. In the past most lenses were designed in the following formats: 160mm / 170mm / 210mm / 240mm. In recent years many objectives have been designed for an infinity tube length. This is to accommodate various intermediate optics, illuminators, and accessories to be placed between the objective and eyepieces. Most of the infinity systems incorporate a lens in the optical path to extend the tube length.

Numerical Aperture

The most important factor in defining the performance characteristics of an objective lens.

$$N.A. = n \sin q$$

n: The refractive index of the media at 587nm
(For dry objectives, n= 1.00, air)
q: Half angle of the incident rays to the top of the lens

The higher the N.A., the higher the resolving power.

Resolving Power

Defined as the power to recognize or distinguish two adjacent points.

$$R = \frac{wavelength}{2\ N.A}$$

Depth of Focus (DOF)

The higher the N.A., the shallower the depth of focus

Field of View (FOV)

Describes the actual field size that is viewed or imaged

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Typical Data for Objective Lenses and Video

Objective	*Typical Range N.A.*	*Range Resolving Power*	*F.O.V. 10x E.P.**	*F.O.V. ½" CCD*	*F.O.V. 2/3"CCD*	*Approx. Field Depth*
5X	.10	2 um- 3.5 um	2600 um	1000 um- 1200 um	1300 um- 1500 um	14 um
10X	.2 - .25	.8 um- 1.0 um	1700 um	450 um- 600 um	600 um- 800 um	3.5 um
20X	**.30 -.40**	**.6 um .7 um**	**850 um**	**230 um- 290 um**	**300 um- 370 um**	**1.3 um**
40X	.40 -.55	.45 um- .5 um	400 um	120 um- 140 um	150 um- 200 um	.5 um -.9 um

*Eyepiece

Magnification / Resolution

After determination of the physical limits and resolution of an objective, it is important to know what magnification is required to resolve an object to the eye or camera. Visual acuity of the eye and resolution of the video camera / monitor help to determine these factors. Image contrast cannot be generated where none exists. The lower the contrast of the initial image, the greater the disturbance caused by optical and electronic noise. There is a constant "tug of war" and compromise between an attempt to increase resolution and keep down the noise level. When the brightness or signal from the image is limited, one needs to fine tune the magnification to find the best balance.

There is no advantage to be gained by increasing the magnification as no more detail in the sample or object can be made visible. Generally this additional magnification without increased resolution is referred to as "empty magnification".

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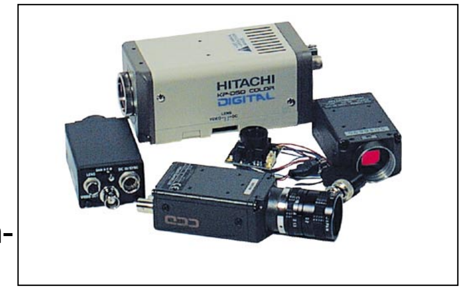
Electronic Magnification

Product of optical magnification times video magnification



Optical magnification = primary lens multiplied times any video lens incorporated between the objective and CCD camera.

Video magnification is defined as the ratio of the diagonal of the monitor divided by the diagonal of the camera chip size.

The size and specifications of the current CCD cameras are actually derived from the older tube type cameras that were ½", 2/3" and 1 inch in physical size. The CCD type camera chips are not actually ½", 2/3" or 1" but are the sizes listed below:

Standard CCD Camera formats

1/3"	Actual Active CCD	=	3.6mm x 4.8mm
½"	Actual Active CCD	=	4.8mm x 6.4mm
2/3"	Actual Active CCD	=	6.6mm x 8.8mm
1"	Acutal Active CCD	=	9.6mm x 12.8mm

Modulation Transfer Function

MTF is a measurement of the ability to capture or transfer the contrast at a particular level of resolution from the sample to the image screen. The best sample to interpret MTF is by using a line pair art of black / white line pairs. The image contrast is expressed as white on black = 100% and ray on gray as 0%. Micro Enterprises is in the process of developing a test sample of line pairs to test resolution and contrast of our image systems. MTF involves a combination of factors of each component in a system.

There are numerous factors to be considered when considering the performance of a video system for microscopic imaging. Some of these are listed below:

1. Visual acuity of the eye
2. Illumination
3. Quality and N.A. of the objective lens
4. Resolution and quality of the video camera
5. MTF
6. Resolution and contrast quality of the monitor

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Approximate Video Magnifications

Camera Format	**Monitor Size**			
	9 Inch	12 Inch	13 Inch	20 Inch
1/3"	38.1x	50.8x	55.0x	84.7x
½"	28.6x	38.1x	41.3x	63.5x
2/3"	20.8x	27.7x	30.0x	46.2x
1"	14.3x	19.1x	20.6x	31.8x

The most common cameras we use at Micro Enterprises are all considered high resolution of at least 570 lines in a format of ½" or 2/3". We are constantly testing and evaluating cameras and monitors for resolution and contrast quality. Our general choice has been Hitachi and Sony equipment. We are now offering high resolution digital format cameras for our ME3200 series microscopes.

When choosing video equipment, there are several important factors to consider:

1. Horizontal lines of resolution
2. Gain functions
3. Minimum illumination (lux)
4. Gamma correction
5. Pixel count
6. Pixel size
7. Signal to noise ratio

There are literally hundreds of camera / monitor choices on the market that areused for many applications. Our choice of industrial grade, machine vision quality cameras offer durability and resolution with all of the appropriate controls and electronics to offer consistent quality images. We have actually tested several different manufacturers' cameras with the exact same specifications that do not offer the same image quality as Sony and Hitachi provide.

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Fiber / Video Magnifications / Pixel count

Calculated using ½" CCD / Used on ME2500 series scopes
Camera Pixel Area 768 x 494

Objective	Fiber Size 12" Monitor	Video Magnification	Micron Size per Pixel	Pixel Size of Fiber
5x	25 mm	200 x	1.56 um x 2.02 um	80 pixel x61 pixel
10x	51 mm	425 x	1.28 um x 1 um	98 pixel x125 pixel
20x	**106 mm**	**875 x**	**.30 um x .59 um**	**416 pixel x211pixel**
40x	215 mm	1720 x	.16 umx .28 um	781 pixel x446 pixel

Calculated using 2/3" CCD / Used on ME2500 Series Scope
ME3200 scope will vary slightly
Camera Pixel Area 768 x 494

Objective	Fiber Size 12" Monitor	Video Magnification	Micron Size per Pixel	Pixel Size of Fiber
5x	20 mm	160x	1.95 umx 2.63 um	64 pixel x48 Pixel
10x	40 mm	320x	1.04 umx 1.21 um	120 pixel x103 pixel
20x	**83 mm**	**664x**	**.48 umx .61 um**	**260 pixel x204 pixel**
40x	165 mm	1320x .	2 umx .4 um	625 pixel x312 pixel

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Pixel Depth / Grayscale

Pixel depth represents the amount of steps of gray in an image. This is closely related to the minimum amount of contrast detected by the CCD sensor. The Video cameras we use offer 256 shades of gray.

Gain

The gain settings control the amplification of the signal from the CCD chip. Most cameras have automatic gain or AGC that can be turned off and set manually or set to a fixed gain. We prefer the fixed gain to enhance any defects on the fiber.

Gamma

The gamma setting controls the grayscale reproduced on the image. An image gamma of unity (1) indicates that the CCD is precisely reproducing the object grayscale (linear response). A gamma setting much greater than unity results in a silhouetted image in black and white, while a gamma setting of less than unity yields a soft gray image. Gamma can be seen as the abilityto stretch either black or white of the dynamic range of the pixel.

Optical Fiber / Connector Inspection

Optical fibers within a highly polished white ferrule are extremely difficult to image, particularly at low magnifications. The image of the fiber (using a 5x or 10x objective) equals less than 20% of the overall pixel area of the camera. Because of this low percentage of area, the gamma and gain of the camera attempt to balance the grayscale on the fiber (black dot) against a white background without much success. Higher quality CCD cameras face the same difficulty unless software is introduced to filter and adjust the gamma beyond 1.

Higher magnifications (20x and 40x objectives) naturally offer a greater percentage of contrast across the pixel array. The pixel size of the fiber is 50% + for the 20x and 40x lens.

The higher N.A. and resolution of the objectives combined with the capability of the camera to more evenly balance the gamma, gain, and contrast of the overall field of pixels make the 20x and 40x the best choice for high quality inspection.

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Summary and Conclusion

Each Customer has their own specifications and criteria for in process inspection. Optical and video inspection involving magnification both incorporate many important factors to achieve optimum results.

A. Are the optics clean and free of debris or fingerprints?
B. Is the illumination adequate and properly aligned?
C. Quality and N.A. of the objective lens and eyepiece
D. Video camera and monitor quality equal to the demands

The original question of "What magnification am I using?" does not have a clear answer regarding video inspection vs. optical inspection.

In our opinion, video magnification or electronic magnification, does not have a direct correlation to optical magnification. The deciding factor has to be the primary inspection lens and the resolution of that lens. If you reference the charts above it appears that you could image or view micron size defects using a lens less than 20x, but we do not feel this is reasonable considering the type of sample under inspection. A 2um x 1um deep scratch is nearly impossible to see visually or with video using a 5x or 10x objective.

The visual inspection requirements of at least 200x requires an objective lens of 20x and an eyepiece of 10x to achieve specific resolution. Therefore we would recommend the video inspection be based on the use of an equal lens of 20x regardless of the final video magnification.

The combination of inspection using the 20x objective and the overall advantages of the pixel size, gain, and gamma functions of the camera offer the best combination to visually obtain equal resolution on a video monitor. It must be noted however, that in some cases the quality of the video system can possibly surpass the quality of a visual system using a 20x objective. Both are operator dependent but the video is less tiring to an inspector than visual. Many customers are now requiring the use of the 40x lens for tighter specifications and higher quality of inspection for single mode fiber.

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The science of microscopic inspection seems to be a never-ending endeavor to achieve the maximum results within the limits of the physics involved. Video has advanced considerably during the past 10 years and the technology will continue to advance, but the limitations of optics will always dictate the final results. Digital video and image processing offer many advantages to enhance the optical image quality, but the cost differential can't always be justified.

Thank you very much for your business and co-operation with Micro Enterprises. Our valuable customers have helped us considerably through the years with suggestions and improvements to further enhance our products and continue to develop new products for the industry. We are currently in the process of major expansion during early 2000 as we introduce new products and expand our production facility. We hope that the next decade will surpass the last for us and our customers.

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