Fringe Elements

Understanding the meaning of interferomentry terminology is key to avoiding misinterpretations.

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In optics, a "wave" and a "fringe" are common terms to indicate a unit of measure. By wave, people generally mean one wavelength from a standard source such as a red helium neon (HeNe) laser. A wavelength (in air) is a unit of length like an inch or a millimeter. A wave refers to an optical path length that may not equal a physical distance in the optics. By fringe, people generally mean half a wavelength. Beware!

If I say that I want something to be "three long," you'd have to ask, "Three what? How long is one?" If the unit (meaning "one") is an inch, then you know that 3 units equals 3 in., and if the unit is a kilometer, then I'm asking for 3 km. If I specify 3 cm and you only have an inch ruler, you know that every inch is 2.54 cm, and so it's 3 cm × 1 in./2.54 cm = 1.1811 in.

Remember this: A FRINGE is not a unit of length. When FRINGES are specified, you must confirm the test configuration. And when WAVES are specified and you need to look at fringes, think consciously about where the light has been.

Let's try this with wavelengths. The HeNe wavelength in air is 632.8 nm. That means there are 632.8 nm per wave. If we read $\lambda/10$ at the HeNe wavelength, that means $\lambda/10 \times 632.8\ \text{nm}/\lambda = 63.28$ nm. One micrometer expressed in HeNe wavelengths is $(1000\ \text{nm}/1\ \mu\text{m}) \times (1\ \lambda/632.8\ \text{nm}) = 1.58\ \lambda$. One wave at 589 nm ($\lambda_D$) expressed in HeNe wavelengths is $1\ \lambda_D \times (589\ \text{nm}/\lambda_D) \times (\lambda_{HeNe}/632.8\ \text{nm}) = \lambda_{HeNe} \times (589\ \text{nm}/632.8\ \text{nm}) = 0.9307\ \lambda_{HeNe}$.

So far, so good, right? Now let's talk about fringes. This is where everyone gets confused, so we need to honor a picky distinction that is often overlooked, and we need to state an incontrovertible but almost universally misunderstood fact. First, the picky distinction: A fringe is *not* a unit of length. Fringes are only the result of two or more beams interfering. They exist nowhere but the plane of interference. It's up to you to know how the beams got there and where they've been.

Now for the incontrovertible fact: Whenever two beams interfere, one fringe equals one wave of optical path difference at the plane of interference. Always.[1] Yet everyone says, "A fringe is a half of a wave." How can these both be true? The dichotomy is a result of our natural inclination toward economical speech.

In most cases, for example in test plates and standard Fizeau interferometer setups, the light travels a round trip from the reference surface to the test surface and back. Thus, the light has gone out and back, and a round trip accumulates twice the surface error we're measuring. The full, correct statement is that "When testing an optic in a round-trip (double-pass) configuration, one half-wavelength of surface deformation causes a round-trip change in optical path length of two half-wavelengths, and one wavelength of optical path deformation causes one fringe of interference." But who has time to say all that? So after generations of opticians using test plates, we say a fringe is a half wave, and we're right . . . most of the time. It's incorrect just often enough to ruin a contract and a reputation. Exceptional situations include reflected wavefronts, oblique incidence, some null tests, buried surfaces, single-pass interferometers, and others.

Again, remember this: A fringe is not a unit of length. When fringes are specified, you must confirm the test configuration. And when waves are specified and you need to look at fringes, think consciously about where the light has been. Test plates and surface interferometry at normal incidence produce fringes equal to one-half wavelength of surface height distortion, and double-pass transmission produces fringes each representing one-half wavelength of single-pass transmitted wavefront. If you're ever in doubt, trace the path of the interfering beams through the entire test setup to the plane of interference, where one fringe represents one wave of accumulated optical path difference.

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References

1. R. Williamson, Proc. SPIE 1527, p. 252 (1991).