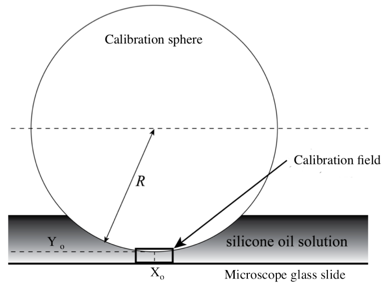


FIGURE 1. Experimental setup for calibration of the measurement technique.

## 1. Thin Film Measurements

For quantified measurements of film thickness under bubble, fluorescence microscopy was employed. Fluorescent dye dissolved in a fluid solution produces a characteristic emission band when it is excited with a light source. The intensity of the emission was recorded with a camera. According to Beer-Lambert law, the intensity is proportional to the film thickness:

$$t = \alpha I \tag{1}$$

where $t$ is the thickness of the film, $\alpha$ is the proportionality (or calibration) constant, and $I$ is the intensity in arbitrary units. This assumption is valid when the liquid film thicknesses is less than a millimeter.

In order to calculate the constant $\alpha$ and relate intensity to the film thickness, this measurement technique needs to be calibrated. A small sphere with a known radius was dropped in a pool of the liquid-dye solution (e.g. silicone oil with fluorescent dye) on a microscope slide (Fig. 1). As the sphere approaches the bottom, the liquid film between sphere and glass slide decreases. By capturing intensity changes during falling using an inverted microscope and relate the values to sphere's geometry profile and film thickness, it is fairly easy to find the value of the calibration constant $\alpha$,

If the equation of a sphere is expressed as:

$$(y - Y_0)^2 + (x - X_0)^2 = R^2 \tag{2}$$

where $X_0$ and $Y_0$ are the center of the sphere and R is the known radius. The location of $Y_0$ can be determined by the relation

$$Y_0 = R + y_{min} \tag{3}$$

where $y_{min}$ is the height of some film of liquid between the surface of the calibration sphere and the glass slide.

Plugging in Eq. 3 and 1 into Eq. sphere, we get

$$I(x) = -\frac{1}{\alpha}\sqrt{R^2 - (x - X_0)^2} + \frac{R}{\alpha} + I_{min} \tag{4}$$

where $I_{min}$ is the minimum value of intensity, which corresponds to $Y_0$. Therefore, By fitting Eq.4 to the intensity profile obtained with an inverted microscope and fixing the radius $R$, we can obtain the following fit parameters: $\alpha$, $X_0$, and $I_0$. Using this technique, we are able to measure very thin thicknesses of films under bubble in a non-invasive manner.