Lumens without an integrating sphere.

The correct way to measure total light output from a bicycle headlight
or flashlight is with an integrating sphere:
<<https://www.google.com/search?q=integrating+sphere&tbm=isch>>
<<https://www.youtube.com/watch?v=mvyptpA-BmY>>
These are not cheap, although they can be home built. There are also
other ways to do it (lumen tube):
<<http://s1074.photobucket.com/user/mrsdnf/media/stuff/IMG_3226.jpg.html>>
<<https://www.youtube.com/watch?v=xOE1ykJ5WAU>>

My method is far from accurate, but good enough for estimating and
comparing the light output of flashlights and bicycle headlights. To
make it work, you'll need a tape measure and a lux meter. I'm using
this one:
<<http://www.ebay.com/itm/381903904643>>
It's main advantages are that it does auto ranging, has a max hold
feature, and is cheap.

First, the math:
1 lux = 1 lumen per square meter.
That means if I project a circular spot on the wall, with an area of 1
square meter, the indicated brightness in lux equals the approximate
lumens output, which can be read directly from the lux meter. Notice
that it is NOT important to know the beam width or the distance
between the light source and the wall.

How big is a 1 square meter spot?
Area = Pi \* radius^2
For Area = 1 square meter the radius of the spot is:
r = sqrt(1/Pi) = 0.564 meters
The diameter of the spot is 1.12 meters (44 inches).

Find a darkened room with a suitable wall, and put two pieced of
masking tape on the wall separated by 1.12 meters (44 inches). Notice
that the wall does not need to be flat or painted white. Half way
between the two markers, hang the lux meter.

To measure, turn on the lux meter and punch the max hold button. This
will display and hold the highest reading. Start well back from the
wall, turn on the flashlight, and slowly move towards the wall until
the edge of the light spot lands on top of the two markers. Turn off
the light and read the meter. The meter reading in lux will be equal
to the lumens output of the flashlight or bicycle headlight.

I bought various flashlights on eBay and tested them at maximum
brightness with new batteries.
This one claims 5000 lumens but delivers 200 lumens.
<<http://www.ebay.com/itm/322447023467>>
This one claims 300 lumens but delivers 97 lumens.
<<http://www.ebay.com/itm/391639378962>>
This one claims 6000 lumens, but delivers 212 lumens.
<<http://www.ebay.com/itm/201457081072>>

There are plenty of problems with this method. Putting the lux meter
at the center of the circle causes the meter to favor lights with hot
spots in the middle. A properly designed bicycle light or flashlight
should have an even and equal brightness distribution across the spot
on the wall, but this is rarely the case. I'm working on a more
accurate way to measure and calculate the average light output.
Probably, it will be measuring the light in the center and along the
edge, and taking an average or estimating the total based on a
gaussian light distribution. Or maybe not putting the lux meter in
the center of the circle. That's for later.

Another error is the color temperature of the light. LED's come in a
variety of color temperatures. The lux meter has a different
sensitivity at each of these colors where the sensitivity curve
follows the sensitivity of the human eye.
<<https://image.slidesharecdn.com/ivanperrepresentationfor24-141008071626-conversion-gate02/95/pls-2014-is-measuring-led-illuminance-with-a-lux-meter-accurate-19-638.jpg>>
Comparing lights with different color temperatures will be a problem.

There is also a problem in dealing with the 1 square meter area when
the spot is not a perfect circle, but rather an ellipse as in many
bicycle headlights.
Area = Pi \* major\_axis\_radius \* minor\_axis\_radius
This can be easily measured, but will be different for each headlight
with an elliptical beam pattern and will therefore be a bit more
complicated to measure.