What resolution is 35mm film?

I've been asked this question a few times lately, so I thought I'd put a "proper" answer together and post it here. Just to make things clear by the way, I'm in no way an expert on this! If you know better feel free to correct me.

The first thing to get clear is that "resolution" is only really a useful term when talking about electronic (and specifically digital) images. The difficulty is that whilst in a digital imager the sensor is made up of photoelectric cells, all arranged in a neat uniform matrix, all (usually) the same size, film just doesn't work in the same way.

Very basically, in a strip of colour 35mm film you have three emulsion layers that are coated with gelatine packed with minute grains of silver halide. Each of these layers responds to the additive primary colours (Blue, Green, Red) and produces a latent image in the silver halide grains. These grains are coupled to subtractive primary colour dyes (Yellow, Magenta, Cyan) that when developed create the actual image on the film. To put it simply, a ray of green light hitting the film causes the silver in the green layer to react. When developed, it will produce an image in the magenta dye.

This immediately throws up several problems when discussing "resolution" with regards to film:

The silver halide grains are distributed randomly, so from frame to frame the "pixels" making up the picture are in completely different places, and there will be a different number of them.

The grains in each layer are actually of three different sizes. The larger the grain, the faster it reacts to light – it is this way that film gets its large range from deep shadows to bright highlights.

The grains are completely random shapes too, so don't make neat square (or rectangle) dots.

Unlike a sensor pixel, a single grain does not react uniformly to light. As an extreme example, if a grain falls across a hard line in a picture (i.e. a black edge against a white background) half the grain will react whilst the other won't (a pixel would read it as a shade of grey).

Essentially what this means is that you can't measure the number of grains in a frame and relate it to resolution. To make things even more complicated, in colour film the silver grains are washed out in the bleach bath anyway just leaving the image in the dye (so actually, talking about "film grain" is something of a misnomer when discussing the processed image).

So can we take the final image on the processed film and use that as a way to determine resolution then? Funnily enough, it just ain't that simple! First let's start with a single frame – it's made up of three layers (YMC) that hold the principle components of the finished image. In its initial stage that's likely to be in negative (we'll assume you didn't shoot reversal). So a black area in your initial shot will have had no effect on the silver halide grains in that area, they won't have created an image with the coupler dye and the resultant image on the negative will be completely transparent. With no grains or dye making this area of the picture up it technically has no "resolution" at all – it's just a piece of see-through film. Conversely an area of the picture that was bright white will have had a large effect on the silver grains in every layer in the corresponding area of the film, so there will be a dense amount of dye making the area black. This of course all then gets reversed when you move to the positive stage.

So where does this leave us when attempting to determine "resolution" in film?

The number of "pixels" making up the image changes depending on the brightness of any given area of picture – bright areas have little-to-no "resolution", dark areas have very dense "resolution".

This distribution of "pixels" occurs separately in each layer, so a red part of the image (in the positive print) will have a dense number of "pixels" in the yellow and magenta dyes and none in cyan.

The dyes, though coupled to the silver halide grains in each layer, don't exactly follow the pattern of the grains – they tend to "cluster" round the grains that have

reacted to light.

The dyes transition between densities very smoothly, making it difficult to determine at what exact point it might have changed shade (which of course ultimately is a factor of how minutely you're measuring it and how sensitive your equipment is).

The problem this leaves us with is that, assuming we have an accurate way to measure "resolution" in the print, it will actually be different in different areas of the picture. If you take the picture as a whole, you're then into the issue of how bright or dark the image is (sunrise in the desert will have less "resolution" than a raining cityscape at night).

So what we're left with when we talk about resolution with regards to film is actually how much detail can be perceived in the image. Again, this turns out to be far from simple to determine. Due to the fact that the image actually changes its structure from frame to frame (due to the random distribution of the silver halide grains), the cumulative affect through time is actually an increased resolution over any single frame. Let me explain…

Let's say (for some bizarre reason) you want a static shot of something that doesn't move (say you're taking a shot of the Mona Lisa). Although nothing in the frame moves, each frame that makes up the shot is structured differently to the one before and after it. The grains are positioned differently, so each frame is picking up slightly different details in the painting. When you run the film at 24 fps, you see each of those individual pictures in quick succession – your brain translates the details of each frame into a single moving image. If you studied each frame in turn, you may notice less detail than when several are run at speed. So resolution then becomes a function of time. Of course, you won't often shoot a totally still image (why bother when you could just take a photo?), so the issue then becomes complicated because your subject or camera (or both) will be moving.

At this point it all becomes very subjective. There is no real test that can determine what "resolution", or more accurately how much detail compared to a digital image, film actually has. Various tests have been done, but ultimately it

relies on converting 35mm film into a digital format and then comparing it to a pure digital one (doing the reverse produces completely different results!) Kodak and Fuji will both tell you that correctly exposed modern 35mm film has far more detail in it than even the best digital formats currently available. Certainly 35mm images scanned at 6k have proved to be more detailed than those scanned at 4k. But then you get into the argument “can the human eye detect differences this high” (personally I’d say yes – my understanding, though limited, of the human eye tells me it can determine far more than anything that can be artificially reproduced in any medium) and (the argument I hate most) “can the average cinema-goer tell the difference, and do they really care?” or the way I translate it “your average punter is stupid, so let's serve them up some crap – they won’t notice”.

There are all sorts of arguments you could get into around respective quality comparisons of film and digital, but at the end of the day it tends to come down to taste. Certainly I’ve always preferred the look of film to the look of digital and I have to admit I’m not much bothered about why. Whether digital can (or even should) accurately emulate the look of film in future I’ll leave to others to debate. For me, digital will almost certainly replace film one day purely due to the benefits in time, cost and ease-of-use. If that’s going to happen, I want digital to be the best it possibly can before the transition finally takes place. 4K is a starting point for that, I’m hoping that the likes of Red (and others) won’t stop there but will keep pushing the technology and quality of digital far into the future.

As for now, what resolution is 35mm film?

It isn’t.

Stephen Webb