Blog post

More on tattoo ink colours and fluence

I recently wrote about how we can use any wavelength to target any tattoo ink colour. It seemed to touch a raw nerve as quite a few people didn't agree with my findings. So, I thought I'd elucidate with a wee bit of physics…

And I know how much y'all love physics!!

Physics

Back to basics – light is composed of photons of energy. That energy is directly linked to the photon's frequency, which is determined when it is created inside an atom. That frequency cannot be changed – it is fixed forever. Hence, each individual photon's energy is also fixed forever.

When a photon encounters another atom's electrons, they have a little 'dance'. If the photon's frequency precisely matches the electron's 'energy gaps', then there is a high probability that the electron will absorb that photon's energy and jump into a higher orbit around the atom's nucleus.

But, this is not the atom's natural state, so that electron will drop back into its original orbit very soon after. As it does so, it will 'give back' the energy it stole from the photon. Depending on quantum mechanical rules, that energy will either be released as heat energy, or as a new photon with the same frequency as the original absorbed photon.

But, the thing is, there are many possible routes for this. Each atom will have many, many different electron gaps, allowing for many paths to absorption. Some will be much more likely to occur than others – it all comes down to probability. If you know anything about quantum mechanics, you will know that everything in the universe is a 'probabilistic event'!!

So, that's the absorption process.

Laser tattoo removal

In tattoo removal, we want the ink atoms to absorb lots of photons, which will be released as heat, to boil the surrounding tissue water and instigate the reaction we're after. To ensure a good response, we need as many photons to be absorbed by the ink as possible.

To achieve this efficiently, we want to match the photon energies with the ink's absorption coefficient – i.e. ensure that the photon frequencies match the electrons' energy gaps.

Of course, we cannot possibly know these!! Who knows what the energy gaps in blue, green or red inks?!! Not me!

So, we need to 'guess', based on previous experiences.

But the fact is that the absorption process is a probabilistic process, meaning that the more photons we fire at an atom, the more likely something will be absorbed. The way we fire more photons is by increasing the laser energy.

Temperature rise

There is a simple equation which illustrates this nicely:

$$dT = \frac{\mu H}{\rho c}$$

Here, 'dT' is the rise in local temperature (of the ink particles), 'µ' is the absorption coefficient of the ink particles, 'H' is the absorbed fluence (no idea why it's denoted 'H' and not 'F'!!), and 'ρc' is a constant which depends on the physical properties of the ink.

In essence, 'µ' is the ink colour. So, the equation tells us that if we fire a fluence 'F' at some tattoo ink with an absorption coefficient 'µ', then it will rise in temperature by an amount 'dT' degrees.

So, let's translate this into Scottish (a unique variation of English!!)…

What this means is that we can achieve a desired rise in temperature, dT, by applying the correct fluence, F. If a different target has a lower absorption, µ, then we need to compensate for this lower absorption by increasing the fluence.

The absorption coefficient of an ink colour depends on the wavelength – or, more correctly, the photon frequency. If we change to a different wavelength (frequency) in our lasers, then the absorption coefficients of the inks also change.

In essence, what this means is that we can use any wavelength (which determines the absorption µ) as long as we set the fluence, F, accordingly, to achieve the desired rise in temperature.

Biology

Of course, none of this considers the biological effects in the skin. This is where the biology takes over, as I discussed in my previous post.

Changing the laser wavelength is not a case of simply matching the ink colour – we must also consider the other potentially damaging effects it may have on the other tissues, such as blood and melanin. When we change wavelength for some particular ink colour, we also change it for other skin constituents.

This means we also change the absorption coefficients for those constituents too. In some cases, this may mean that the absorption is now stronger in the blood and melanin leading to higher temperature rises on those tissues too. ‘μ’ tends to increase significantly as the wavelength drops through the visible spectrum.

Hence, my concerns on my previous post – be sure to consider the other effects which may occur when changing wavelengths.

And, as I mentioned previously, the equation above tells us that we can target all colours with all wavelengths – we just need to find the most appropriate fluence to achieve the same result.

Summary

This post has been a bit ‘physics heavy’ but I hope I’ve made it clear enough. Laser tattoo removal is a bit tricky in that we can never know exactly what we’re trying to treat. Most ink colours are a blend of a number of different inks – with different absorption coefficients. This makes it trickier to figure out how to best treat them!

Hope this helps a bit,

Mike.

PS Don’t forget about our next MasterClass inn Glasgow in February 2024.