Practical applications of Quantum measurement techniques in pharmaceuticals and biologic activities

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1 Introduction

Quantum technology is very new and promising area of contemporary science including the sub-branches : quantum optics, quantum mechanics, quantum computing, etc. As is described in several sources [1] the tern Quantum refers to a description as the minimum amount of physical property involved in an interaction. In quantum optics this is most often a single photon or in other cases any sub-atomic particle such as neutron, proton or electron. One of the distinguished characteristics of quantum mechanic is that [2], "In classical mechanic, when something happens it happens for a reason, but in quantum mechanics (world) events can occur without any reason ". In quantum experiments the particles exhibit very interesting behaviours such as existing in two different places with 50% possibilities each (superposition), communicate with each other whatever distant they are (entangling), and pass through the barrier without any interaction with it (quantum tunnelling)

This report is mainly supported by the experiments done by utilizing a basic level quantum interferometer (Mach-Zehnder) in our electro-optics lab, based on quantum physical principles so that a laser light at 532nm wavelength (simulating single photons) is emitted into the interferometer and the light beam is splitted by two paths by interferometer optics then join together at the end producing an interference pattern (wave property). The pattern is stimulated by interaction between the interferometer's lower or upper arm and a substance under investigation (e.g. chamber with gas, liquid, etc.) or a different medium whose refraction index differs from normal condition. Pattern is also modified by dislocation of interferometer's components like its mirror or lens by a microscopic pressure on it.

The application fields of quantum measurement technique would be unlimited but in this report it has been categorized as below :

1) Tablet characterization
2) Tablet or pharmaceutical substance dissolution
3) Water vapour behaviour analysis
4) Dynamic microorganism activities
5) Interaction-free measurement (needs additional detector sensors)

2 The system configurations

Supplementary components have been added to original interferometer setup (Figure 1) such as horizontal translation stage (with micrometer drive), liquid/gas chamber, camera, vibration absorbers, etc. The modifications of the original setup have been shown in Figure 2 and 3.

In the first modified form, the substance under investigation (e.g. tablet) is subject to a controlled pressure by a translation stage (with micrometer drive) where some amount of the pressure is indirectly transferred to the interferometer's component (mirror) which causes gradually changes on pattern fringes. The time-sequenced dynamic information extracted from the pattern changes correspond to tablet characteristics (e.g. density, elasticity, strength, etc.) as shown in Figure 2 by the formula (1) ;

$$\frac{N.\lambda}{2} = m - \alpha \,; \qquad m = d + \alpha \qquad (1)$$

Where;

N : Number of fringes counted
λ : laser light Wavelength
d : displacement of interferometer's component.
α : displacement of tablet
m : translation stage micrometer reading

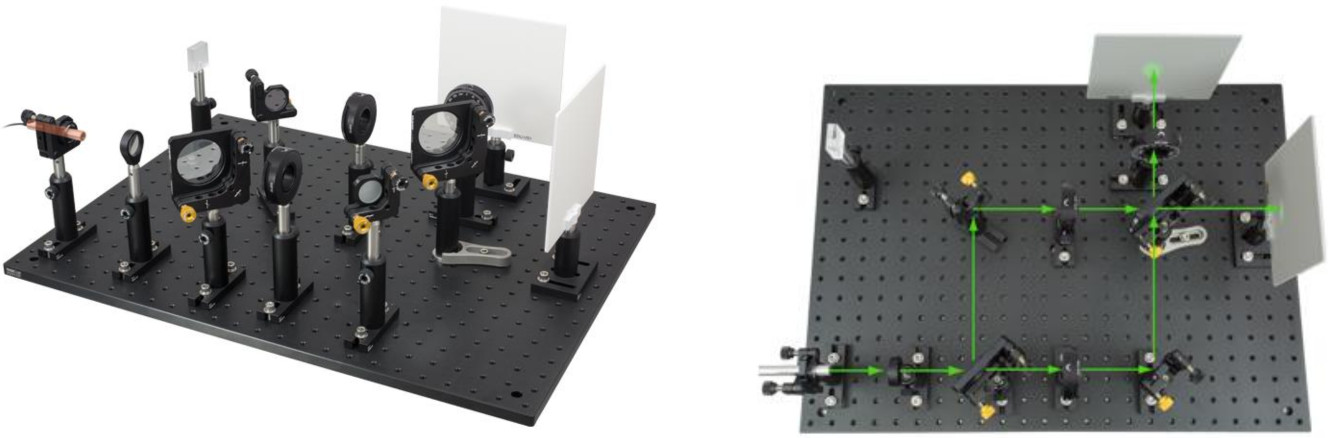

Figure 1. Original configuration of Mach-Zehnder interferometer (side view and top-down view)

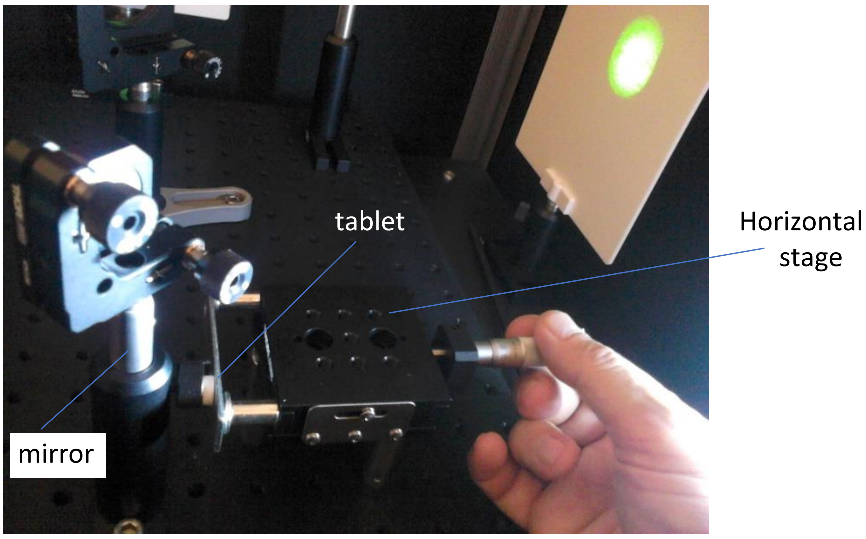

Figure 2. Modified version of the interferometer with the addition of horizontal translation stage (with micrometer drive)

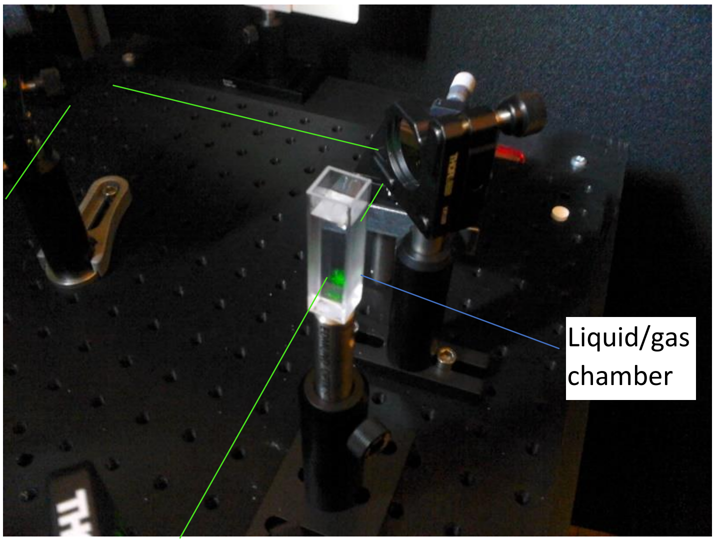

Figure 3. Modified version of the interferometer with the addition of liquid/gas substance chamber

In the second modified form of interferometer (Tablet dissolution, Water vapour behaviour analysis or Dynamic microorganism activities modes) as shown in Figure 3, one of the laser beams (interferometer arm) pass through the test chamber filled with liquid solvent for tablet dissolution, watervapour/gas substance or microorganisms sample under investigation. The time-sequence characteristic changes in the sample would be observed by pattern variation which can be quantised by its number of fringes as stated in the formula 2 [3]

$$n = \frac{(2t - N\lambda)(1 - cos\theta)}{2t(1 - cos\theta) - N\lambda} \qquad (2)$$

Where;

t : thickness of chamber
θ : rotation angle of chamber
N : number of fringes
λ : laser wavelength
n : refraction index of substance in the chamber

In the setup (Figure 3) rotation angle of chamber is constant as it is fixed, hence rotation parameter may be omitted. Any changes in the substance characteristics in the chamber would alter refraction index value and consequently lead to interferometric pattern changes. The substance would be any material like a solvent in which a tablet dissolution is observed via pattern changes. It would be dynamic water vapour or microorganism sample.

Conclusion

The potential applications of quantum measurement system based on Mach-Zehnder interferometer is exponentially increasing by inspiration of quantum world which fundamentally differs from the classical physics. Particularly the field “interaction-free measurement” would provide a more ground breaking ultra-sensitive measurement for lower “sub-atomic” level of pharmaceuticals or any other substance that may convey very early information of any process before it is contaminated by the environmental effects. The proposed methods will also be supported by the increasing number of experiments accomplished by the quantum technology institutions on global based.

References

[1] Wikipedia (2018), https://en.wikipedia.org/wiki/Quantum

[2] Gerry, C.C. and K.M. Bruno (2016). The quantum divide, Oxford University Press, UK

[3] Amrita University, Michaelson interferometer, YouTube 2013. https://www.youtube.com/watch?v=lzBKlY4f1XA