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# Concept of Information Laser: from Quantum Theory to Behavioral Dynamics

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**Abstract** Recently, the methods of quantum theory, especially quantum information, started to be widely applied outside of physics: in cognitive, social sciences, economics, finance, decision making and biology. We propose a quantum-like model: the “information laser”. The basic assumption is the discrete structure of state spaces related to the quantization of information. The information field acts in the form of indistinguishable quanta of “social energy” analog to photons. The massive flow acts as a pump. In this framework an information selection process by agents under constant pressure of massive repeated information leads to collective “resonance” effects in analogy with laser cavity and stimulated emission. In order to make operational parallels between physical lasers and the information laser we identify the essential features of laser operation. An application to the analysis of recent disruptive social events (color revolutions) is discussed.

The formalism of quantum mechanics is now widely explored to describe biological, cognitive, psychological, and socio-political phenomena. This formalism provides the consistent probabilistic picture of observations performed for systems exhibiting (statistically) quantum-like features: from cells, animals, and humans to societies and ecosystems. In particular, in recent papers [1, 2] the model of *Stimulated Amplification of Social Actions (SASA)* was presented describing a kind of information laser device. It has to be outlined that at the very beginning of laser research, parallels have been made between laser behavior and other disciplines, considering the laser concept as a general principle with potential applications outside physics, for example in the *Synergetics* approach by H. Haken [3] where the focus was put on the laser phase transition and non-linear dynamics analogy and in the works on the laser statistical aspects by M. Lax [4].

On a more fundamental level the quantum features at the origin of laser action remain an open question. A full quantum analysis of a laser [5], leads to involved quantum diffusion Fokker-Planck equations using quantum operators. The concept of a laser has been evolving with the better understanding of laser physics. At the beginning a laser was understood as a source of an intense, sharp beam, but it was soon realized that the high intensity was not the only attribute of a laser, one must also consider its coherence, or photon statistics, that constitutes the most fundamental distinction of laser light from light of a usual lamp. The coherence of a laser is more specifically described by the first- and second-order correlation functions which are very popular in quantum optics. One of the important points of practical importance is to determine when a light emitting device has exceeded the so-called threshold and becomes a laser. Recently, an interesting discussion between H. M. Wiseman [6] and W. Elsässer [7] highlighted an important point: a crucial property of laser light above threshold is that a laser must have stable intensity, more precisely that the intensity fluctuations become insignificant and only phase fluctuations contribute to the statistics of a laser beam.

A motivation of the approach presented here is to define the operational conditions of a laser using system parameters, not relying on specific laser technology, these parameters can then be extrapolated to domains outside physics. Beyond the well-known rate equations for atomic populations and photons, describing the internal mechanisms of a laser, quasi-classical models for the laser coherence characteristics can be used. A constant diffusion Fokker-Planck equation on the phase probability distribution permits to describe the different behaviors below and above threshold. A complete analysis for semiconductor laser using this approach was developed in [8], demonstrating laser coherence and phase transition behavior in agreement with experimental results.

The physical laser ( $\Phi L$ ) parameters permitting to give a faithful system description of laser behavior are: - the laser frequency  $\nu$  of the photon in the two-level energy transition  $E_2 - E_1 = h\nu$ ; - the output laser power  $P$  issued from the laser cavity related to the total photon number  $n$ ; - the pump power rate  $R$  linked to inversion  $\Delta N$  below threshold and to power  $P$  above; - the laser spectral width  $\Delta\nu$ , this last parameter relates the degree of coherence; - the laser cavity characterized by the photon lifetime  $T_p$  linked to cavity dimension  $L$  and reflection coefficient  $R$ ; - the amplification bandwidth  $\Delta\nu_g$ . Internal parameters can be derived from these by well-known laser equations for example for the spontaneous emission time  $T_{sp}$ .

The concept of *information laser (IL)* consists of the following basic elements: - a quantum information field; - its excitations; - quanta of information; - gain medium; - agents. The additive energy transmitted by the information field is absorbed by the agents, it is the *social energy*. The agent gain medium emits and absorbs discrete portions of social energy so that agents belonging to the same social medium produce stimulated emission.

The information field contributing to the social energy can be associated with the photon number  $n$ , and is independent of the frequency. The *color* of the social energy is on the other hand represented by frequency and coherence and is induced by the filtering/selecting process by agents under constant pressure of massive continuous information, leading to resonance effects as in a laser cavity. The massive flow acts as a pump of indistinguishable information accumulating continuously, the result is SASA.

| <i>laser feature</i> | <b>Physical Laser <math>\Phi L</math></b> | <b>Information Laser <math>IL</math></b> | <b>System parameter</b> | <b>Internal parameter</b> |
|----------------------|---|--|-------------------------|---------------------------|
| <i>pump</i>          | input pump power                          | exciting information field               | $R$                     | $\Delta N, g$             |
| <i>amplification</i> | atomic gain                               | behavioral agent gain medium             | $\Delta \nu_g$          | $g, T_{sp}$               |
| <i>frequency</i>     | photon energy                             | social color                             | $\nu$                   | $E_2 - E_1$               |
| <i>mode</i>          | optical cavity                            | repetition/selection of information      | $T_p$                   | $L, r$                    |
| <i>power</i>         | optical power                             | rush of social energy                    | $P$                     | $n$                       |
| <i>coherence</i>     | spectral linewidth                        | definiteness of social color             | $\Delta \nu$            | $T_p, T_{sp}$             |

**Table 1:** Parameters for Physical Laser and Information Laser.

An application can be sought for the analysis of new socio-political phenomena such as the so-called “color revolutions” which initiated in the territories of the former Soviet Union and in the Balkans. Recently similar features in western democratic systems originated from protests against government corrupted system. For example a group of excited humans imposed to the intensive flow of communications, say about corruption of the state leaders would emit quanta generating actions against corruption of state leaders - a coherent wave of anti-corruption protests. These phenomena are the subject of numerous studies and publications in political and social sciences (see [1, 2] for references). An adequate theory for these dramatic socio-political phenomena is still lacking. In this situation, it seems motivating to explore the correspondence and to define a methodology based on the laser formalism in order to explain the outburst of these phenomena.

This work has also the goal to identify the possible causes of instability in a complex environment leading therefore to prevention guidelines for decision making. One of the most striking features of SASA is *indistinguishability* which is a central methodological issue of application of the mathematical formalism of quantum theory to social science.

## References

- [1] A. Khrennikov, “Towards information lasers”, Entropy, 17, No. 10, 6969-6994 (2015)
- [2] A. Khrennikov, “Social laser: Action amplification by stimulated emission of social energy”, Phil. Trans. Royal Soc., 374, No 2054, 20150094 (2016)
- [3] H. Haken, “Synergetics”, Springer, (1977)
- [4] M. Lax, et al. “Random Processes in Physics and Finance”, Oxford University Press (2006)
- [5] H. Haken, “Light vol. II: Laser Light Dynamics”, North-Holland Physics Publishing, Amsterdam, (1985)
- [6] H. M. Wiseman, “How many principles does it take to change a light bulb into a laser?”, arXiv:1510.04805, (2015)
- [7] W. Elsässer, “Comment on “ How many principles does it take ...”, arXiv:1607.03647, (2016)
- [8] Z. Toffano, “Investigation of threshold transition in semiconductor lasers,” IEEE J. Sel. Topics Quantum Electron., vol. 3, no. 2, 485–490, (1997)

