Review on Social Laser Theory and Its Applications

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Abstract This is a review on social laser theory completed with its new developments and applications. An important methodological step toward similarity with quantum physics is the invention and consistent operation with infons. These are excitations of the quantum social-information field carrying social energy and coarse-grained content of communications (their color and quasi-color). We study in more detail interactions of infons with social atoms, the processes of absorption and emission (spontaneous and stimulated). We also analyze the dynamics of iterations of the cascades of infons in the social resonators. The latter are based on social networks coupled to laser's gain medium composed of social atoms. Consideration of the pro-war and pro-peace beams leads to the general discussion on the competing beams of social radiation and the conditions for their creation and coexistence. The role of social networks in lasing is illustrated by the protests during the COVID-19 pandemic. It is highlighted that a human gain medium can approach the state of population inversion with the supply of infons of one sort (quasi-color), but the stimulated emission can be induced by injection into the gain medium of infons of a different quasi-color. We call this behavior of social atoms memorylessness. This theoretical property is illustrated with the examples from the modern social-political life.

Keywords Social laser · Social energy · Social atom · Indistinguishability · Quantum statistics · Quantum information theory · COVID-19 protests · Pro-war and pro-peace beaming

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1 Introduction

Nowadays the formalism and the methodology of quantum theory are widely used in applications outside of physics, especially in cognition, psychology, and decision-making as well as in social and political sciences (see, e.g., monographs Khrennikov 2004, 2010; Busemeyer and Bruza 2012; Asano et al. 2015; Haven et al. 2017; Bagarello 2019). Such applications are known as *quantum-like*—to distinguish them from real quantum physics, including its applications to cognitive science (quantum physical reductionism). The majority of the quantum-like models are based on quantum mechanics (QM), but for the social science one has to appeal to the formalism of the quantum field theory (QFT). One of the most intensively developed QFT-theories is the social laser theory (Khrennikov 2015, 2016, 2020a,b; Khrennikov et al. 2018, 2019; Alodjants et al. 2022). This chapter is a review on this theory completed with its new developments and applications.

The basic entities of this theory are social energy, atoms, and fields (Thims 2008; Khrennikov 2015, 2016, 2020a,b; Khrennikov et al. 2018, 2019; Alodjants et al. 2022) (cf. also with James 1890; Freud 1957; Jung 2001; Jung and Pauli 2014). Social atoms represent humans. They exchange quanta of social energy with the social-information field which is composed of excitations carried by communications massively emitted by mass media and social networks. The lasing scheme can be formulated with these entities as the process of social energy pumping in a human gain medium and then stimulated emission of a cascade of social actions. The latter are understood very generally as actions in both physical and social-information spaces: mass protests, color revolutions, wars, and collective decisions on the important societal problems.

This chapter is an important methodological step toward approaching similarity with quantum physics. We invented the social-information analogs of photons which are called *infons*. These are excitations of the quantum social-information field carrying social energy and coarse-grained content of communications (their color and quasi-color). We study in more detail interactions of infons with social atoms, the processes of absorption and emission (spontaneous and stimulated).

We also analyze the dynamics of iterations of the cascades of infons in the social resonators. The latter are based on social networks coupled to laser's gain medium composed of social atoms. The special attention is paid to the role of Echo Chambers. They increase color and quasi-color coherence of the social-information field.

The role of social networks as lasing resonators is illustrated by the massive protests during COVID-19 pandemic (cf., e.g., van der Zwet et al. 2022).

Consideration of the pro-war and pro-peace beams generated since February 2022 in mass media and Internet resources leads to the general discussion on competing beams of social radiation and conditions for their creation and coexistence. The role of social networks is highlighted once again (cf. Khrennikov 2020b).

Social laser theory predicts that a human gain medium can approach the state of population inversion with infons of one sort (quasi-color), but the stimulated

emission can be done by injection of a batch of infons of a different quasi-color *memorylessness of social atoms.* This is a very important property of social laser which can be widely used in social engineering. We illustrate this theoretical property with a few examples from the modern social-political life.

In this chapter we shall widely use the abbreviation *s*- for "social," say *s*-atom and *s*-energy.

2 Social Atom

A human is the minimal indivisible entity of society, a social atom (*s*-atom). The atomic viewpoint on the human being has a very long history; see Thims' book (Thims 2008), in this book the reader can find discussions and references on the basic human-atomistic (or molecular) models.

Although the authors of such models suggested a different definition, generally they follow the same paradigm: operating with human beings as individual information processors described by just a few parameters characterizing information interaction. Thus, practically infinite complexity of a human being was reduced to these basic parameters, in the simplest case to social energy. This reduction of complexity made humans treatable thermodynamically. On the other hand, ignoring human complexity diminishes the explanatory power of such models; typically, they can describe statistical behavior of humans but not explain why they behave in one or another way.

The distinguished property of our approach is the quantum-like treatment of variables, as representing observations performed on *s*-atoms. Another distinguished property is the invention of the quantum information field, i.e., *s*-atoms can interact not only with each other, as in aforementioned theories, but also with the social-information field which is also interpreted and modeled in the quantum-like framework. Such modeling is supported by the resent development of the information approach to quantum theory.

3 Social Energy

From the very beginning of QM, Bohr denied the objectivity of quantum variables, such as position, momentum, or energy. They cannot be treated as properties of systems and assigned to them before measurement. Measurements' outcomes are generated in the process of complex interaction between a system and a measurement device (Bohr 1987).

This approach is fruitful for the introduction of *s*-energy. We do not need to create a deep neurophysiological or psycho-social theory to justify this notion (cf. James 1890; Freud 1957; Jung 2001; Jung and Pauli 2014). *S*-energy is an observable measuring the degree of social excitement of a person. It can be done with a

variety of measurement devices. They can be calibrated with different scales, and the simplest scale is dichotomous, $E = E_{a0}, E_{a1}$, where these values are assigned to relaxation and excitement, respectively.

The simplest measurement procedure is done with question: "Do you feel your socially excited or not?" From the quantum operational viewpoint, such invention of the s-energy observable seems to be justified. In the future quantum-like modeling, the crucial role will be played not by the absolute values of the energy levels, but by their difference:

$$E_a = E_{a1} - E_{a0}. \tag{1}$$

If both levels are high, but the energy gap is small, then such s-atom would not be able to perform a strong social action. Say, she would never participate in demonstrations leading to brutal clashes with police.

The energy levels determine the corresponding mental states of an s-atom which are denoted as $|E_{a0}\rangle, |E_{a1}\rangle$. The main feature of quantum representation of states is the existence of superpositions, e.g., s-atom can be not only in the mental states $|E_{a0}\rangle, |E_{a1}\rangle$, corresponding to the concrete values of s-energy, but also in superposition states of the form:

$$|\psi\rangle = c_{a0}|E_{a0}\rangle + c_{a1}|E_{a1}\rangle, \text{ where } |c_{a0}|^2 + |c_{a1}|^2 = 1, c_{aj} \in \mathbf{C}. \tag{2}$$

The complex coefficients c_{aj}, $j = 0, 1$, encode the probabilities, and $p_j = P(E = E_j|\psi) = |c_j|^2$ is the probability that s-atom in the mental state $|\psi\rangle$ would answer that her s-energy equals E_j. (Here we consider the introspective measurement procedure of s-energy when s-atom is asked to report her energetic feeling and the set of answers is restricted to "I feel me relaxed" and "I feel me excited.")

This probability depends on the state $|\psi\rangle$ of s-atom, and this fact is reflected in the symbol $P(E = E_j|\psi)$. This formula is Born's rule, the basic quantum rule providing the probabilistic interpretation for the linear algebra on the state space $\mathcal{H}$ of s-atom. The latter is a complex Hilbert space. In this simple case it is two-dimensional with the orthonormal basis $|E_{a0}\rangle, |E_{a1}\rangle$ (qubit space). As is typical in physics, the scalar product of two vectors from $\mathcal{H}$ is denoted as $\langle\psi_1|\psi_2\rangle$. In terms of the scalar product of s-atom's states, the Born rule is written as

$$p_j = |\langle E_{aj}|\psi\rangle|^2. \tag{3}$$

The existence of superposition states is the mathematical expression of non-objectivity of s-energy. Until s-atom is not asked to estimate her s-energy, she does not know its value. Of course, one can design other methodologies for the measurement of s-energy which are not based on self-observations.

4 Social-Information Field

In accordance with QFT, a field represents an ensemble of its energetic excitations. Mathematically this excitation structure of a field is described in Fock space. Quantum fields are described with the operators of creation and annihilation of excitations.

Quantum field excitations are treated on equal grounds with "real systems" such as atoms or electrons. Say excitations of the electromagnetic fields are photons. Moreover, excitations corresponding to vibrations, e.g., of atoms in a crystal or dipoles in a molecular, also treated as systems, phonons.

In social studies we proceed in the same way. The social-information quantum field is an ensemble of energetic excitations, and each excitation is determined by the portion, "quantum," of s-energy. The field excitations are generated by the sources of socially relevant information, mainly by mass media and social networks. Each communication emitted by them carries a quantum of s-energy. We call such quanta *infons*.

In physics photon's energy can be connected with light's frequency and hence the color. In the same way we can color infons, depending on s-energy: low and high s-energy infons are colored as red and violet, respectively, and for intermediate coloring we can use other colors; say yellow infons are sufficiently energetic, but still not exciting. For example, during the pandemic the majority of communications on COVID-19 were of the violet color; during the spring of year 2022 news about the war was also violet, but the communications about COVID-19 were colored in red. News about sexual affairs of politicians and stars can be colored in yellow.

We hope that this s-energy/color terminology will not be misleading. In ordinary life red means danger and attracts more attention than violet. But, in physics red photons are low energetic and violet photons are highly energetic. We keep the physical picture. So, the red colored infons carry small amounts of s-energy and violet infons are highly energetic.

In fact, in physics the characterization of QFT excitations is not reduced to energy. For example, a photon also has polarization. Generally photon's state $|E\alpha\rangle$ is characterized by the parameters E = energy and α = (polarization, temporal and spatial extensions). Social-information field can also have some characteristics additional to s-energy and related to communication's content. We call such characteristics the *quasi-color* of infon; its state can be encoded as $|E\alpha\rangle$, where E and α are s-energy and the quasi-color, respectively.

Introduction of the quasi-color is a delicate process related to such foundational issue as *indistinguishability of quantum systems* (see, e.g., Ballentine 1998). Quantum theory assumes that two photons in the state $|E\alpha\rangle$ are indistinguishable. Moreover, it is claimed that there are no hidden variables and additional photon's characteristics which would provide a possibility to distinguish two photons in the state $|E\alpha\rangle$. So, in quantum physics indistinguishability has the fundamental character. Indistinguishability plays the crucial role in derivation of quantum

statistics for energy distribution in the framework of *statistical thermodynamics* (Schrödinger 1989).

In quantum-like modeling of the social-information (s-information) field, infons are indistinguishable, up to s-energy E and the quasi-color α. This is the important assumption beyond social laser theory. However, there is one important difference between quantum and quantum-like indistinguishabilities. The former is genuine and irreducible and the latter is relative to context. In one context some social variables are important and they should be included in the quasi-color α, and in another context they do not play any role, so they are not included in α. But, we cannot deny their existence. For example, humans have names, but their names do not play any role in the process of social lasing in the form of mass protests. So, humans are indistinguishable w.r.t. to the name variable. The slogan "Black Lives Matter" is the integral quasi-color which was crucial in the protests in USA. The concrete names of black people who experienced racism, discrimination, and racial inequality were hidden in this quasi-color.

So, indistinguishability in social laser theory is quantum-like. It is up to the characteristics determining the process of lasing. These characteristics form the quasi-color α. And infons' indistinguishability is up to s-energy and this quasi-color.

5 Absorption and Emission of Infons by Social s-Atom

Here we consider processes of absorption and emission of quanta of s-energy by s-atoms interacting with the excitations of the social-information field—infons.

Consider physical atoms with two levels of energy, excited and relaxed, E_1 and E_0. The difference between these levels

$$\Delta E_{\mathrm{a}} = E_{\mathrm{a}1} - E_{\mathrm{a}0} \tag{4}$$

is the basic energetic parameter of an atom, its spectral line.[1]

A two-level atom reacts only to photons carrying energy E matching with atom's spectral line (Bohr's rule):

$$\Delta E_{\mathrm{a}} = E. \tag{5}$$

In quantum-like modeling we apply Bohr's rule to s-atoms and infons. So, a two level s-atom reacts only to infons carrying energy E matching atom's spectral line, see (4) and (5).

[1] In the case of two-level atom, it has just one spectral line. Generally there are a few spectral lines corresponding to differences between energy levels, $\Delta E_{\mathrm{a};ij} = E_{\mathrm{a}i} - E_{\mathrm{a}j}$, $i > j$. This is the atom's spectrum.

If infon carries too high energy which is larger than the spectral line, $E > \Delta E_a$, then this s-atom would not be able to absorb this infon. For example, infon carrying s-energy E is a call for upraise against the government. And s-atom is a bank clerk (say Elena) in Moscow. Elena has the liberal views and hates Putin's regime, but her spectral line is too small to absorb s-energy carried by such infon and to move from the ground state to the excited state. She simply ignores such highly energetic communication, news, or Internet post. Similarly, if infon's s-energy E is less than spectral line ΔE_a, then Elena would not be excited by such infon.

As a physical atom cannot collect energy from a few low energy photons, with $E < \Delta E_a$, s-atom cannot collect s-energy from a few infons carrying small portions of s-energy. S-atom either absorbs infon (if their colors match each other) or does not react to it. In the same way, s-atom cannot "eat" just a portion of s-energy carried by highly energetic infon with $E > \Delta E_a$.

In the quantum-like theory the process of infon emission by excited s-atom is also characterized by its spectral lines. In the case of two-level s-atom, this is just the number ΔE_a. S-atom can emit only infon satisfying (5).

As in physics, emission can be spontaneous when s-atom suddenly emits infon—at random instance of time and with a random quasi-color. Another sort of emission is known as stimulated; s-atom emits infon as the result of interaction with infons of surrounding social-information field. Ideally a single infon in the state $|E\alpha\rangle$, where $E = \Delta E_a$, stimulates excited s-atom to emit infon in precisely the same state. So, emitted infon has not only the same s-energy as stimulating infon but also the same quasi-color α. However, since this process is probabilistic (as all quantum-like processes), the real stimulation of emission is possible only with fields of high density. So, s-atom should interact with a strong social-information field, with a cloud of excitations that have the same s-energy (equal to ΔE_a) and quasi-color. Inside such a field the probability of emission is high.

In quantum physics spontaneous emission of photon by atom is considered as exhibition of irreducible quantum randomness. However, such picture might be adequate only for completely isolated atom. But real atom is never completely isolated. Background radiation is everywhere. Therefore, it may be that even the spontaneous emission is not a totally random process. It can be stimulated by fluctuations of the background electromagnetic field and interactions with other atoms. In the same way spontaneous emission of s-excitation might be generated by fluctuations in surrounding social environment: occasional news, a scandal with a partner, a problem at work, and so on. The quasi-color which emitting s-atom assigns to infon (or action in physical space generated by this infon) may reflect the environment's quasi-color.

In physics the photon absorption-emission condition (5) is satisfied only approximately

$$E \approx \Delta E_a. \tag{6}$$

The spectral line broadening is always present. In an ensemble of atoms, $\Delta E_a = \Delta E_a(\omega)$ is the Gaussian random variable. This is a bell centered at the mean average

value $\Delta\bar{E}_{\rm a}$. The dispersion of the Gaussian distribution depends on an ensemble of atoms. Ensembles with small dispersion are better as gain mediums for physical lasing, but deviations from exact law (5) are possible.

It is natural to assume Gaussian distribution realization of exact laws even for social systems, in particular, absorption of excitations of the information field by s-atoms. Thus, deviations from (5) are possible. But a good human gain medium (an ensemble of s-atoms selected for social lasing) should be energetically homogeneous. Therefore, the corresponding Gaussian distribution should have very small dispersion. The latter is also an important necessary condition for functioning of physical laser.

Finally, we discuss one interesting feature of interrelation of absorption and emission: Consider quantum physics. Suppose that an atom absorbed a photon with momentum vector $\vec{p}$. This vector determines the direction of photon's propagation and its length $|\vec{p}|$ determines the photon's energy. The process of absorption is characterized by matching of energies (5), so the direction of photons propagation given by

$$\vec{\alpha} \equiv \vec{p}/|\vec{p}| \tag{7}$$

does not play any role in the process of absorption. The most interesting for us is that atom "forgets" the direction $\vec{\alpha}$ of incoming photon. In the process of spontaneous emission, an atom emits a photon in an arbitrary direction. Moreover, in the process of stimulated emission, an atom emits a photon with momentum which is identical to momentum of stimulating photons, the stimulating electromagnetic field.

The same "memory washing" is a feature of quantum-like model since its mathematical formalism is identical to quantum physical theory. So, s-atom does not remember the quasi-color α of infon, say a news, which it has absorbed. It can emit spontaneously infon, say a post in a social network, of an arbitrary quasi-color. When s-atom is stimulated for emission, it emits infon of the same quasi-color as stimulating infons, say news. This memorylessness of social atoms is very important in social engineering, including social lasing.

Turning to quantum physics, we note, in contrast to direction $al\vec{p}ha$ (7), photon's polarization.

6 Social vs. Physical Lasing Schematically

For simplicity we consider two-level atoms, both physical and social. We shall present the social lasing scheme parallelly to the scheme of physical lasing.

6.1 Laser's Components and the Stages of Lasing

Physical laser has three main components:

- A gain medium composed of atoms
- A source of energy (the electromagnetic field)
- A resonator (an optical cavity)

Physical lasing has two main stages:

- (A) *Energy pumping.* Energy is pumped into a gain medium; the aim is to approach the *population inversion*—more than 50% of atoms should be transferred into the excited state.
- (B) *Stimulated emission.* A batch of photons propagating in the same direction α given by (7) are injected into the gain medium. They stimulate the cascade process of the emission of photons by atoms.

At both the stages the colors of photons and atoms' spectral line match each other at least approximately. We recall that we consider two-level atoms and there is just one spectral line. The gain medium should be color-homogeneous. Photons produced during the B-stage copy the direction of propagation from stimulating photons. The latter were injected along the main axis of the optical cavity—laser's resonator. As was pointed out, the directions of photons' propagation at the A and B stages can be totally different (memorylessness of atoms). Some important details will be mentioned below to illustrate the corresponding details of social lasing.

The social laser also has three components:

- A gain medium composed of s-atoms (humans)
- A source of s-energy (the social-information field)
- A social resonator (Internet-based social networks)

Social lasing also has two main stages:

- (A) *Energy pumping. S*-energy is pumped into a human gain medium; the aim is to approach the *population inversion*—more than 50% of s-atoms should be transferred into the excited state.
- (B) *Stimulated emission.* A batch of infons of the same quasi-color α are injected into the gain medium. They stimulate the cascade process of the emission of infons by s-atoms.

Now we describe these stages in more detail:

The mass media and Internet pump s-energy into a gain medium composed of s-atoms to approach the *population inversion*—to transfer the majority of atoms to the excited state. The gain medium should be homogeneous w.r.t. its spectral structure, ideally $\Delta E_{\mathrm{a}} = \text{Const}$. In reality ΔE_{a} is a Gaussian random variable with very small standard deviation. The s-energies of infons (communications, news, messages, Internet videos) used for energy pumping need not be so sharply concentrated around average $\overline{\Delta E_{\mathrm{a}}}$ of ΔE_{a}. S-atoms would simply ignore infons

essentially deviating from $\overline{\Delta E_a}$. And such s-energy losses are compensated by the powerful flows of information generated by modern mass media and Internet.

After achievement of the population inversion, the stimulated emission is started. A batch of infons (say communications, news) is injected into the human gain medium. The first constraint is that s-energy of these stimulating infons should match the spectral line of s-atoms, see (5) (in the ideal case). In reality it is sufficient to control the approximate matching condition (6). So, s-energy of injected infons should not deviate essentially from $\overline{\Delta E_a}$. Another constraint on injected infons is that they all should carry the same quasi-color α, say α =COVID-19, or α = vaccination, or α = Russian aggression against Ukraine (depending on socio-political context and aims of social lasing). This injected beam of information radiation generates the cascade process in the human gain medium.

Quasi-color homogeneity of the stimulating information injection is the basis of quasi-color coherence of the laser beam of infons. Later this social-information beam is transferred into the social action matching infons' color (s-energy amplitude) and quasi-color (information content). Infons' homogeneity should be very high. Here statistical deviations are not acceptable, since infons of other quasi-colors would also generate their own cascades. Such "noise-cascades" would destroy quasi-color coherence of the output beam of social radiation. They should be then eliminated with the aid of social resonators.

6.2 How Does the Cascade Process Evolve? The Role of Laser's Resonator

In the simplified picture, each infon stimulates s-atom to emit infon having the same color and quasi-color with its stimulator. Resulting two infons stimulate two s-atoms to emit two new infons, so one stimulating infon resulted in four infons which interact with four s-atoms and so on. After say 20 steps there are 2^{20}, approximately one million of infons (the excitations of the social-information field) of the same color and quasi-color. In reality, the process is probabilistic: s-atom reacts to stimulating infon only with some probability. The latter rapidly increases with the increase of the density of the social-information field. And the field's bosonic nature is crucial.

In physics the beam induced in the gain medium by the stimulating injection of coherently colored photons is not the laser's output beam. Laser has an additional component which plays the crucial role in increasing both the amplitude and coherence of the output beam. This is a *laser resonator*. For lasers emitting photons—excitations of the quantum electromagnetic field, this is an optical cavity. Its mirrors reflect beams generated inside the gain medium and send them back to this medium. In this way the cascade process in the gain medium is repeated many times.

The process of reflection from the mirrors also increases *spatial coherence* of the beam. The photons propagating not precisely along the main axis of the cavity are reflected outside of the cavity and disappear. We remark that the stimulating beam is sent along this axis. The cascade photons copy the direction of propagation in space given by momentum vector (7) of initially injected photons.

We remark that during the beam iterations (through reflections) energy is continued to be pumped into the gain medium from outside. So, atoms that emitted photons in the preceding iterations absorb newly incoming photons and move to the excited state. Intensity of pumping of energy quanta into the gain medium should be high enough, higher than some threshold depending on laser's parameters. This threshold is called the *lasing threshold.* If the intensity of energy pumping is lower than the lasing threshold, then too many atoms would spontaneously relax between two reflection-iterations of the basic wave of photons. On the one hand, this is the energy loss, and on the other hand, the mini-cascades created in the excited gain medium by spontaneous emissions would lower coherence of the radiation beam. If the intensity is higher than the lasing threshold, then practically all energy pumped into the gain medium is transferred into the basic radiation wave propagating along the cavity's axis.

In our quantum-like model the social laser also should have a resonator, a kind of two mirrors that reflect infons and send them back into the human gain medium—to interact again with s-atoms in the human gain medium and to stimulate them to emit infons. The role of such social resonators is played by Internet-based information systems, such as You Tube, Facebook, Instagram, Bastyon, Telegram, Life Journal, VK, and so on. The main distinguishing feature of these systems is the possibility of the rapid feedback to communications, news, and videos in the form of comments, comments on comments, and so on. The beam of infons created from the initial stimulating injection (typically by mass media's giants as say BBC and CNN, Washington Post, New York Times, and Guardian) is distributed over Internet channels and creates new posts (in the form of articles and videos), each of them is actively commented. Each comment plays the role of a mirror. But this is a kind of an active mirror, not only reflecting infons but also creating them.

The social resonator and also the physical resonator not only amplify the beam of social radiation inside the human gain medium but also increase its coherence w.r.t. the quasi-color α of the stimulating injection. Posts quasi-colored differently from α disappear in the massive flow α-infons.

6.3 The List of the Basic Counterparts of Social Laser Theory

- Our quantum-like model is of the quantum field type, the social-information field. Its excitations are called infons. Each infon transports quantum of s-energy. The latter determines infons' color, red infons are low energetic, and violet infons are highly energetic.

- Each s-atom is characterized by the s-energy spectrum; in the simplest case of two levels, this is the difference between the energies of the excitation and relaxation states, $\Delta E_a = E_1 - E_0$.
- Beside s-energy (color), infons (the excitations of the information field) are characterized by other labels, quasi-colors, carrying content of information communications.
- Coherence corresponds to quasi-color sharpness; ideal social laser emits a single quasi-color mode, denoted say by the symbol α.
- Excited s-atoms by interacting with α-colored infons also emit α-colored infons.
- The amount of s-energy carried by stimulating infons (communications) should match the color of s-atoms in the gain medium.
- To approach the population inversion, s-energy is pumped into the gain medium. Pumping should be intensive, since s-atoms have the tendency spontaneously relax and emit infons with randomly distributed quasi-colors.
- This energy pumping is driven by the mass media and the Internet sources.
- The gain medium should be homogeneous with respect to s-energy spectrum. Ideally (for the two-level case), all s-atoms should have the same color ΔE_a. However, in reality, it is impossible to create such human gain medium. As in physics, the *spectral line broadening* has to be taken into account.
- The quasi-colors of infons in energy pumping have no direct connection with the quasi-color of infons generated by stimulating emission (memorylessness of s-atoms).
- Infons follow the Bose-Einstein statistics.
- This statistics matches with the bandwagon effect in psychology (Colman 2003) (see article Khrennikov 2020b for details).
- The probability of emission of the α-colored infon by s-atom in a human gain medium increases very quickly with the increase of the intensity of the social-information field on the α-colored mode.
- The stimulating injection of homogeneously quasi-colored infons gives rise to the cascade of coherent (w.r.t. the color and quasi-color) infons.
- The created beam of social radiation is amplified in the social resonators based on Internet information systems, say YouTube, Facebook.
- The social resonators, especially in the form of Internet-based Echo Chambers, also improve quasi-color coherence (Sect. 7).
- When the power of the beam of coherent infons becomes very high, infons are transformed into social actions, either in physical or in information spaces.

For example, a gain medium consisting of humans in the excited state and stimulated by the anti-corruption quasi-colored information field would "radiate" a wave of anti-corruption protests. The same gain medium stimulated by an information field carrying another quasi-color would generate the wave of actions corresponding this last quasi-color. For social laser engineering, it is very important that the quasi-colors of s-energy supply and stimulation of emission do not need to coincide. Population inversion can be approached with, say the quasi-color α, and then the stimulated emission can be generated with another quasi-color β.

7 Echo Chamber as Reinforcer of Social Coherence

The detailed presentation of social resonators theory can be found in article (Khrennikov 2020b). In the latter we highlighted the differences between the physical resonators of the cavity type, so to say "passive reflectors," and the social resonators which are based on the "social mirrors. Such mirrors can be treated as active reflectors producing on demand of users new infons.

Here we shall consider in more detail special but at the same time very important type of social resonators, namely, Internet-based *Echo Chambers* (see also Khrennikov 2020b). In our notations it can be defined as follows:

> Echo Chamber is a system in that some beams of infons carrying (as their quasi-colors) news, communications, ideas, and behavioral patterns are amplified and sharped through their feedback propagation inside this system. In parallel to such amplification, infons carrying quasi-colors different from those determined by the concrete Echo Chamber are suppressed.

In our terms, an *Echo Chamber is a device for transmission and active re-emission (not simply reflection) of infons—the excitations of the quantum social-information field.* Its main purpose is amplification of this field and increasing its quasi-color coherence via distilling from "social noise," i.e., infons colored and quasi-colored differently from Echo Chamber's basic color and quasi-color.

We underline that an Echo Chamber is considered as a component of the social laser, as its resonator. The coherent output of an Echo Chamber, the quasi-color of this output, is determined not only by the internal characteristics of the Echo Chamber but also by the quasi-color of stimulated emission in laser. The same Echo Chamber may be turned in accordance with the aim of the stimulated emission in progress. Of course, such turning is not possible for every Echo Chamber. Some of them are stable w.r.t. to their basic quasi-colors.

Amplification and increasing of coherence w.r.t. to Chamber's quasi-color have already been discussed for general social resonators. What about sharpening? Generally s-atom's quasi-color is a vector $\alpha = (\alpha_1, \alpha_2, \ldots, \alpha_n)$, where the coordinates represent (as labels) different information contents; each α_j is valued in some space X_j, often $X_j = \{-1, 1\}$ represents the no/yes answers, but more complex quasi-color spaces are also possible, and the simplest such space is $X_j = \{-1, 0, 1\}$, negative, neutral, and positive evaluation of some issue, say the present war in Ukraine.

Let us consider functioning of some Internet-based Echo Chamber; for example, one that is based on some social group in Facebook and composed of s-atoms. The degree of their indistinguishability can vary depending on the concrete Echo Chamber. Say, names are still present in *Facebook*, but they have some meaning only for the restricted circle of friends; in *Instagram* or *Snapchat*, even names disappear and s-atoms operate just with nicknames.

By a social group we understand some sub-network of say Facebook, for example, social group "Quantum Physics." The main feature of a social group is that all posts and comments are visible for all members of this social group. Thus,

if I put the post "Getting rid of nonlocality from quantum physics," then it would be visible for all members of this social group, and they would be able to put their own comments or posts related to my initiation post. This is simplification of the general structure of posting in Facebook, with constraints that are set by clustering into "friends" and "followers."

We assume that the ensemble of s-atoms of this Echo Chamber approached population inversion, so the majority of them are already excited. A batch of communications of the same quasi-color α and carrying quanta of s-energy $E_c = \Delta E_a$ is injected in the Echo Chamber. Excited s-atoms interact with the stimulating communications and, with some probability, emit information excitations of the same quasi-color as the injected stimulators. These emitted quanta of s-energy are represented in the form of new posts in Echo Chamber's social group. Each post plays the role of a mirror, and it reflects the information excitation that has generated this post.

However, the analogy with the optics may be misleading. In classical optics, each light ray is reflected by the mirror again as one ray. In quantum optics, each photon reflected by the mirror is again just one photon. An ideal mirror reflects all photons, and the real one absorbs some of them.

In contrast, "the mirror of an Echo Chamber," the information mirror, is s-energy *multiplier.* A physical analog of such a multiplier works as follows. Each light ray is reflected as a batch of rays or in the quantum picture, matching the situation better, each photon by interacting with such a mirror generates a batch of photons. Of course, the usual physical mirror cannot reflect more photons than the number of incoming ones, due to the energy conservation law. Hence, the discussed device is hypothetical.

8 Illustrating Examples

In this section we would like to illustrate previous theoretical considerations by the additional examples of social laser's use at the modern socio-political arena, potential, and real uses.

8.1 COVID-19 Protests

During the COVID-19 pandemic the human gain medium was overheated by the shock news about the spread of this terrible disease, by its deadly consequences, by life during lockdowns, and by numerous rigid restrictions on social life (e.g., masks in public places and somewhere, e.g., OAE, even at the streets), by the QR-codes and obligatory vaccination for some professions, e.g., the personal of hospitals. Such communications were often repeated a few times, and their content could vary, but not the basic quasi-color, α = COVID-19. In some countries, even the

most democratic ones as in Sweden, the laws were changed by restricting the basic freedoms, including the basic constitutional right for meetings and demonstrations.

Scientists also actively contributed in generation COVID-19 fear. For example, some mathematical models of disease spread predicted millions of deaths from COVID-19 in UK and hundreds of thousands in Sweden, if the rigid restrictions, including lockdowns and masks, would not be invented (Ferguson et al. 2020).

My personal opinion is that such the mathematical models were really primitive, basically the very old SIR-dynamics (may be disturbed by a stochastic term for noise). This is a good place to mention the new model of disease spread (Khrennikov and Oleschko 2020); it took into account the social cluster structure of population. This model predicted the opposite effect, comparing with the majority of models, of lockdowns and other rigid restrictions. In contrast to, e.g., Ferguson et al. (2020), such restrictions slowdown approaching of natural immunity in human population.

By summarizing we can say that at the end of the year 2020 and the beginning of the year 2021 the state of population inversion was approached in European countries, Australia, Canada, USA, and Russia. The human gain medium was ready for radiating a huge spike of social energy, a spike which could destroy the basics of society. Various social groups and individuals started to generate information excitations against WHO's COVID-19 policy and their governments following this policy. Social networks resonated these excitations. This led to the generation of local spikes of protests, worldwide and especially in Australia, Germany, the Netherlands, France, UK, Canada, and even Sweden (see, e.g., van der Zwet et al. 2022; Chueca and Teodoro 2029). In Sweden the COVID-19 restrictions were really mild compared with the majority of countries: no lockdowns and no masks. However, extended suppression of functioning of the social resonators, especially by YouTube and Twitter, prevented creation of the global wave of protests. At the same time, the local spikes relaxed some portions of social energy, and in this way social temperature was lowed.

8.2 Pro-war and Pro-peace Beaming: Competitions of Stimulating Emissions

Coming back to social goodness lasing theme, consider a war between two countries or blocks of countries. And suppose that some group of policy makers wants to use the social laser technology to generate the wave of peaceful thoughts and actions. Assume that this group is powerful enough to generate a strong injection of communications for peace. In principle, it is possible to connect with a message having quasi-color α = "peace" big amount of social energy. Unfortunately, to generate such social lasing for peace, the war should be going on for sufficiently long time. And it should lead to big casualties from both sides or at least from one of them. Otherwise even spontaneously emitted hate cascade would destroy the processes of stimulation of a cascade of thoughts and actions for peace.

Here we come to the problem of *competing stimulation* in human gain medium approached the state of population inversion.

The main problem in starting such a process is that another group at the political arena might not be interested to end this war. By using their information resources, they could continue social lasing in favor of the war, $\alpha =$"war." And the aggression instinct is so powerful that there is a big chance that such an $\alpha =$ "war" beam of social laser would be essentially stronger than the $\alpha =$ "peace" beam.

In such a competition of social energy beams of two quasi-colors, the crucial role is played by social resonators, in the form of social networks based on You Tube, Facebook, Live Journal, Bastion, Twitter, Telegram, Instagram, Yandex, Vkontakte, and so on. Therefore, it is so important to control such information resources (e.g., one can understand the motivation of Elon Musk to buy Twitter). Without the control of social resonators, it is practically impossible to start stimulating emission. The initial (stimulating) batch of information excitations which is not supported by social resonators would pass through information space in a flash and disappear.

8.3 Russian-Ukrainian War and Relaxation of Social Energy Generated by COVID-19 Pandemic

Now we turn again to the COVID-19 pandemic. As was pointed out in Sect. 8.1, during the years 2020–2021 human society collected a lot of social energy and approached the state of population inversion.

Of course, the state of population inversion was not approached in whole world; say in Egypt and other African countries COVID-19 did not lead to massive transition of people into the excited state. We speak about this transition in European countries (both West and East Europe), USA, Canada, and Australia. It is interesting that in China, in spite of very high degree of COVID-19 related restrictions, generally the mental state of population could not be characterized as excited. Chinese population took these restrictions rather calmly by following automatically to COVID-19 state recommendations, as people here would do in any other case. On the other hand, the mass protests of Canadian track-drivers demonstrated that the degree of social tensions in Canadian society was very high. These protests can be considered as a test of COVID-19 generated instability in Western society.

One can speculate that only the war between Russia and Ukraine relaxed the huge amount of social energy collected during the pandemic in Europe, USA, Canada, Russia, and Ukraine. The COVID-19 energy was transferred into the war energy. Here we discussed mainly the processes in social information space, i.e., not the real war battles in physical space.

8.4 Generation of Financial Tsunamis: Reddit Against Wall Street

For those who did not know or forgot the story about a social network uprising against Wall Street, we recall some details by following (Malik 2021):

> GameStop is a US video game retailer that has lost much of its market share to online trade and whose stock plummeted from $56 a share in 2013 to about $5 in 2019. Some big hedge funds decided that they would cash in on GameStop's misery by shorting its shares. A short is a bet that an asset, such as a share, will decline in price. It's a manoeuvre that can generate huge profits. But if the asset price doesn't fall, investors can also lose a lot of money.
>
> A bunch of Reddit geeks on the online forum r/wallstreetbets, an investment discussion group that boasts more than 6 million users, decided to buy GameStop shares en masse. Perhaps they saw it as an investment, perhaps they were bored, perhaps they wanted to inflict pain on Wall Street. Whatever the reason, the consequence was to push GameStop's share price up. And up. Once it became a global story, others piled in too, boosting the share price from about $40 to almost 400 in a matter of days. As a result, big investors lost big... . The story, however, is not just about traders getting their comeuppance, but also about the absurdity of the stock market.

To analyze this event, we shall appeal to social laser theory with its application to social atoms operating at the financial market. In this framework this "global story" demonstrated not only the absurdity of the stock market but rather the possibility to use new financial technology for generation of short squeezing. And as usually, this GameStop short squeezing generated huge profits for those who designed and ignited the process of stimulated amplification of coherent social actions. In this case "social actions" were posting comments at Reddit expressing believes (hopes, instructions) that GameStopp shares will go up in price. These were actions in the information space. They led to actions in the financial space—buying of GameStopp shares.

We finalize this short consideration of Reddit "uprising" by a few citations from media sources (Sherr 2021):

> And though the share price dipped on Monday, Feb. 1, by more than 30%, many Reddit users say they're buying more GameStop stock, convinced it'll rocket even higher. Jaime Rogozinski, the apparent founder of the Reddit community at the heart of all this, told The Wall Street Journal it's like 'a train wreck happening in real time.' Keith Gill, the trader in the Reddit community who helped kick off the battle, told the paper he 'didn't expect this.'
>
> There might be something cathartic in watching the wolves of Wall Street themselves being savaged, but we should not romanticise the Reddit geeks. This was not an 'uprising' or 'the French Revolution of finance', as Donald Trump's former communications director Anthony Scaramucci absurdly described it, but a scheme to play professional investors at their own game. [Guardian]

9 Concluding Remarks

We hope that this review will be useful for the researchers working in both humanitarian and natural sciences. As was mentioned, the methodology of social laser theory was enriched through the invention of *infon.* This is an analog of photon. Photons are the excitations of the quantum electromagnetic field and infons are the excitations of the *quantum social-information field.* By operating with infons the presentation of spontaneous and stimulated emission and absorption became very similar with its counterpart of the quantum physics based on operation with photons. From my viewpoint, infons are not "less real" than photons or phonons (quanta of vibrations). The same can be said about the social-information field by comparing it with the electromagnetic vibration fields.

We emphasize the bosonic nature of these fields which is the basic factor leading to generation of the cascade process of the stimulated emission in the lasers' gain media, both physical and human. The "bosonicity" is a consequence of indistinguishability of excitations, photons, phonons, and infons. For the latter, indistinguishability is not absolute. Distinguishability is only up to a few characteristics involved in lasing, namely, infon's color (s-energy) and quasi-color (strongly coarse-grained information content—a content label). In physics it is commonly claimed that there are no hidden variables giving deeper description of system's state than the quantum state—completeness of quantum mechanics. Knowing of the hidden variables would destroy indistinguishability. For cognitive and social systems, hidden variables definitely exist, each human has say the passport, and humans can be distinguished by observation passport content. The use of quantum theory in the presence of the hidden variables is a complex foundation issue. It was discussed in a few of my previous publications, e.g., Khrennikov (2010). I cannot say that this issue was completely clarified. At least the contradiction with the violation of the Bell inequalities can be resolved by referring to the contextual character of the mental hidden variables.

The infons-language is convenient to describe the dynamics of cascades' iterations within social laser—the gain medium and resonator. Social resonators are implemented by coupling laser's gain medium to social networks. We emphasize the role of resonators in, e.g., lasing for the competing candidates in the presidential elections. Generally we are interested in the process of creation of two competing beams of social actions, as the mentioned elections or war and peace beams in contemporary information space. Also in article (Khrennikov 2020b), we highlight the role of Internet-based Echo Chambers in increase of the amplitude as well as color and quasi-color coherence of the beams of social radiation. Echo Chambers are also used to increase temporal coherence, to make the spike of social radiation sharply concentrated in the time domain. It is a good place to point out that a social Internet-based resonator is a kind of active mirror, in contrast to the optical cavities with the reflecting mirrors.

Once again (cf. with Khrennikov 2015, 2020b) we highlighted the possibility to supply s-energy to the gain medium with infons of the quasi-color different from

the quasi-color of infons in the stimulating injection (and hence the output beam of social radiation). This property of s-atoms is called *memorylessness.* It plays the important role in *social engineering.* The real aim of social lasing can be deemed at least at the stage of s-energy pumping in the gain medium. Moreover, s-energy produced by one social laser can be used at the stage of approaching population inversion in another social laser. In turn the latter can be used for new social laser and so on.

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