Subject:
What is meant by the denotation “unpolarized light”? The following citations try to give an answer.

“The \( \mathbf{E} \) field vectors of the light wave oscillate in no preferential direction. One refers to polarization when the \( \mathbf{E} \) field vectors move in a well-determined manner. White light is in general unpolarized.”

“In general electromagnetic radiation is the superposition of a great number of single waves with a different orientations of the oscillation planes and with different phases.”

“Natural light is in general unpolarized. It originates in atomic transitions of a great number of atoms. Each atom emits a light wave, whose direction of polarization is statistically distributed in space, so that the plane of oscillation of the emitted light changes steadily.”

Sometimes, unpolarized light is represented by a picture like that of figure 1, which apparently is supposed to be a snapshot of the electric field strength (more exactly: of the tip of the vector arrow) above the position coordinate in the direction of the propagation of the light. One can see various “waves” at the same time at the same place.

Fig. 1. “Snapshot” of the electric field strength vector tip in an electromagnetic wave. Is the wave unpolarized?

Deficiencies:
It is not difficult to understand the concept of a polarized electromagnetic wave. Neither is it difficult to understand how a polarizer works. The question of how we can imagine unpolarized light seems to be more difficult. In school books this question is somewhat neglected.

There are several theories of the light: geometrical optics, classical electrodynamics, quantum electrodynamics and thermodynamics. Depending on which of these theories is applied, the explanation of what is unpolarized light is somewhat different. Here we shall limit ourselves to classical electrodynamics.
The state of polarization of a light beam is best described by making a statement about the behavior of the electric field strength vector in a plane perpendicular to the propagation direction as a function of time; or in graphical representation: about the movement of the vector tip in this plane. (We admit that the light beam is homogeneous in its transverse extension.)

Light can exist in various states of polarization. The most important and best-known are linear polarization, elliptical polarization (with the special case of circular polarization) and the complete absence of polarization.

In the case of linearly polarized light the vector tip describes a harmonic movement, in the case of elliptic polarization an elliptic movement. There are many other possibilities for preparing light in such a way that the vector tip executes a more or less regular movement, among them Lissajous curves. When the light is unpolarized the vector tip moves on irregular curves without any periodicity. The average velocity of this movement depends on the temperature of the light and the length of the vector arrow depends on the intensity of the light. Both the direction and the module change irregularly. We could also describe the vector by its cartesian components. Then we would say: Both the x and the y component of the vector vary irregularly. In both descriptions there are two contributions to the “disorder” of the state of the light and thus to the entropy that is transported by the light beam.

Regarding our citations:

1. The first citation says, that the $E$ field vectors oscillate, and that they do not have a preferred direction. Usually by oscillation we understand a periodic process. However, if the light is white, the vector tip does not make a periodic, but an irregular movement.

2. The second citation says that thermal radiation is a superposition of single waves. This statement goes a little far. First one should specify what is meant by “single wave”. One might believe that a sine wave is meant. Then the single waves would simply be the harmonic components of the light. If that is meant, it would be more appropriate to say that the radiation can be decomposed into such components, just as it can be decomposed in many other ways. But it may be that the harmonic components are not meant. Our third citation gives an indication.

3. “Each atom emits a light wave, whose...”. Here we see, that the light wave cannot be a pure sine wave. Since it originates in one atom it has a beginning and an end. According to a conception that many students have, such a “light wave” is an object that can be individually identified or at least imagined. Here probably the photon is haunting around, but in a somewhat vulgarized form: a small object which resembles a piece of wire that had been given a wavy shape. It conserves its individuality even when it is part of a light beam. Some pictures in text books foster such an idea.

4. Text books often show pictures that illustrate the working principle of a polarizing filter. Sometimes these pictures are like that of Fig. 1. Here three “individual waves” are shown. They have the same wavelength and are in phase. The figure does not show how long they are. When considering only that part which is represented, the superposition results simply in a linearly polarized wave. The idea that the state of the wave is one with a maximum of disorder (of entropy), cannot be seen from the figure.
Origin:
It seems that the problems has several causes.
1. When the students learn that light is a transverse wave, they may believe that the tip of the field strength vector must oscillate in a direction perpendicular to the propagation of the wave.
2. A tendency to believe that a wave consists of spectral components instead of seeing these components as a result of our arbitrary decomposition. The wave seems to consist of them like a book consists of pages.
3. A somewhat naive idea about the photon. Light consists of these individuals, but radio waves do not.
4. The awe to consider the light under a thermodynamical point of view.

Disposal:
White light that is completely incoherent is omnipresent. So, do not hesitate to describe the field strength distribution of such light and discuss the various contributions to the disorder of this state.
Do not speculate about the “true nature” of the light. Remain committed to what we know: How to describe the state of polarization and of absence of polarization by means of electrodynamics. Some thermodynamics in the arguments is not harmful.
Avoid the word oscillation when describing unpolarized light. The field strength vector does not oscillate; it moves chaotically.

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