SPECTROPHONE and PHOTOPHONE or RADIOPHONE.

"Chamber's Encyclopedia" (1880)

The action of these instruments depends upon the phenomena of radiant energy which within a few years have been observed by different physicists, but whose practical results, if the time has arrived when the term may be used, have been principally accomplished by prof. Alexander Graham Bell, the inventor of the speaking telephone in common use, in conjunction with Mr. Sumner Tainter.

The invention of the photophone arose from the employment by Willoughby Smith of selenium as a resistance medium in testing submarine cables. It was found that the resistance of selenium to the galvanic current varied considerably, and the discovery was made that this was caused by the action of light, which lessened the resistance. When selenium is exposed to the action of the solar spectrum, the maximum effect is produced, according to Sale, just outside of the red end of the spectrum, in a point nearly coincident with the maximum of the heat rays (see Radiation in article HEAT, ante), but according to Adams it is produced in the greenish-yellow or most luminous part of the spectrum, and he moreover found that selenium was sensitive to the cold light of the moon.
E. W. Siemens discovered that heat and light produced opposite effects upon some extremely sensitive varieties of selenium. In some of his experiments the resistance on exposure to light was only one-fifteenth of what it was in the dark. It occurred to prof. Bell to substitute the telephone for the galvanometer hitherto used in these experiments on accounted its great sensitiveness to electrical influences; but in doing so it was necessary to vary the action of light so that the intermissions front light to darkness should be sudden, in order to produce a succession of changes in the conductivity of the selenium corresponding in frequency to the musical vibrations within the limits of hearing; and upon further consideration it appeared to him that all the audible effects obtained from varieties of electricity could also be produced by variations of light acting on selenium.
In an article in Science of Sept. 11, 1880, he says: *"I saw that the effect could be produced at the extreme distance at which selenium would respond to the action of a luminous body. But that this distance could be indefinitely increased by the use of a parallel beam of light, so that we could telephone from one place to another without the necessity of a conducting wire between the transmitter and receiver. It was evidently necessary, in order to reduce this idea to practice, to devise an apparatus to be operated on by the voice of the speaker, by which variations could be produced in a parallel beam of light, corresponding to the variations in the air produced by the voice."*
But a difficulty was found in the fact that the resistance of selenium was too great to respond sufficiently to the action of light; this, however, was overcome by reducing this resistance—from some half million ohms to 300 in the dark, and to 155 in the light.

The fundamental features of the selenium photophone are best given in prof. Bell's own words: *"We have devised about fifty forms of apparatus for varying a beam of light in the manner required. The best and simplest form consists of a plain mirror of flexible material—such as silvered mica or microscopic glass. Against the back of this mirror the speaker's voice is directed. The light reflected from this mirror is thus thrown into vibration corresponding to those of the diaphragm itself. In arranging the apparatus for the purpose of reproducing sound at a distance any powerful source of light may be used, but we have experimented* *chiefly with sunlight. For this purpose a large beam is concentrated by means of a lens upon the diaphragm mirror, and minor reflection is again rendered parallel by means of another lens. The beam is received at a distant station upon a parabolic reflector, in time locus of which is placed a sensitive selenium cell, connected in a local circuit with a battery and telephone."*

The loudest effects obtained from light were produced by rapidly interrupting, the beam by a perforated rotating disk, revolving over the face of a perforated disk, with holes corresponding. Audible tunes were produced from the light of a candle.

The experiments connected with the construction of this apparatus led to others with other substances than selenium, and also without the use of telephone or battery.

A thin sheet of hard rubber was held close to the car while a beam of intermittent light was thrown upon it by a lens, the result being the production of a musical note, and this effect was intensified by arranging the hard rubber as a diaphragm and listening through a hearing-tube. The remarkable though natural conclusion was reached *"that sounds can be produced by the action of a variable light from substances of all kinds in the form of thin diaphragms."*

Subsequently prof. Bell arrived at the conclusion that sonorousness under the influence of intermittent light is a property of all matter. Various experiments were made with different fibrous and porous materials, such as cotton-wool, worsted, silks, sponge, lamp-black, etc. These articles were enclosed in a conical cavity, contained in a piece of brass, and closed by a flat plate of glass through which an intermit tent beam of light was thrown upon them. A hearing-tube communicated with the cavity.

Mr. Tainter found that the darkest shades produced the best effects. Black worsted especially gave an extremely loud sound. Cotton-wool darkened with lamp-black gave so loud a sound as to suggest the use of lamp-black alone. Of this substance a tea spoonful, placed in a test-tube and exposed to an intermittent beam of sunlight produced the loudest sound of all, and a piece of smoked glass, with the smoked surface receiving the intermittent beam, gave a fine effect. Upon smoking the interior of the conical cavity of the receiver above-mentioned, and then exposing it to the intermittent beam, "the effect was perfectly startling. The sound was so loud as to be actually painful to the ear placed closely against the end of the fearing-tube."

The various experiments above alluded to will probably be of great importance in telephony as indicating that lamp-black may be substituted for selenium in an electrical receiver. M. Mercadier passed an intermittent beam from an electric lamp through a prism and found a coca in the audible effects in different parts of the spectrum. These experiments were repeated by prof. Bell, with somewhat different results. Under conditions not necessary to describe here, *"sounds were obtained in every part of the visible spectrum excepting the extreme half of the violet, as well as in the ultra-red. A continuous increase in the loudness of the sound was observed upon moving the receiver gradually from the violet into the ultra-red. The point of maximum sound lay very far out in the ultra-red. Beyond this point the sound began to decrease, and then stopped so suddenly that a very slight motion of the receiver made all the difference between almost maximum sound and complete silence."* Removing the smoked wire gauze from the receiver and substituting red worsted different results were obtained, the maximum effect being produced in the green at that part where the red worsted appeared to be black. On either side of this point the sound gradually died away. On substituting green silk for the red worsted the maximum effects were found in the red. A test tube containing the vapor of sulphuric ether was then substituted for the receiver, but no effects were observed till a certain point far out in the ultra-red was reached, when a musical tone was suddenly produced, which disappeared as suddenly further on. With the vapor of iodine the maximum effect was in the green. These, and experiments with other substances, led to the conclusion that *" the nature of the rays that produce sonorous effects in different substances depends upon the nature of the substances that are exposed to the beam, and that the sounds are in every ease due to those rays of the spectrum that are absorbed by the body."*

These phenomena led prof. Bell to the construction of a new instrument for use in spectrum analysis, which was described and exhibited to the philosophical society of Washington last April. *"The eye-piece of a spectroscope is removed and sensitive substances are placed in the focal point of the instrument behind an opaque diaphragm containing a slit. These substances are put in communication with the ear by means of a hearing-tube, and thus the instrument is converted into a veritable spectrophone. Suppose we smoke the interior of our spectrophonic receiver and fill the cavity with peroxide of nitrogen gas. We have then a combination that gives us good sounds in all parts of the spectrum, visible and invisible, except the ultraviolet."*

"Now pass a rapidly intermitted beam of light through some substance whose absorption spectrum is to be investigated, and bands of sound and silence are observed upon exploring the spectrum, the silent positions corresponding to the absorption bands.

Of course the ear cannot for one moment compete with the eye in the examination of the visible part of the spectrum; but in the invisible part beyond the red, where the eye is useless, the ear is invaluable. In working in this region of the spectrum, lamp-black alone may be used in the spectrophonic receiver. Indeed, the sounds produced by this substance in the ultra-red are so well marked as to constitute our instrument a most reliable and convenient substitute for the thermo-pile."

See Science for May 28, 1881. Prof. Bell recognizes the fact that the spectrophone must always be no more than an adjunct to the spectroscope, but believes that it will have a wide and independent field of usefulness in the investigation of absorption spectra in the ultra-red.