The phenomenon of the Soliton, or single wave, one of the principles behind optoelectronics was first demonstrated by John Scott Russell on the Union Canal in 1838

Born in Parkhead, Glasgow, he soon abandoned plans to join the ministry for a career in engineering.

His first invention - a steam carriage - was initially successful, but his enterprise as a steam-coach operator between Glasgow and Paisley came to a sudden end in 1834, when four fatalities resulted from the crash of one of his carriages.

By this time, he was starting to become interested in naval architecture and was commissioned by the Union Canal Company to build three experimental wave line vessels.

While trialling these in 1834, he observed the solitary wave which the boat made when travelling through water. He called it the Soliton and was able to follow it, on horseback, for several miles.

Although the significance of his observation is now attracting renewed attention in the areas of optoelectronics and telecommunications, Russell applied his observations of the single wave effect to the redesign of ships hulls, providing shipbuilders with their first scientific guide in the pursuit of speed.

He went on to design much of Isambard Kingdom Brunels Great Eastern, for many years the worlds largest steamship.

Over one hundred and fifty years ago, while conducting experiments to determine the most efficient design for canal boats, a young Scottish engineer named John Scott Russell (1808-1882) made a remarkable scientific discovery. As he described it in his "Report on Waves": (Report of the fourteenth meeting of the British Association for the Advancement of Science, York, September 1844 (London 1845), pp 311-390, Plates XLVII-LVII).

In 1834, John Scott Russell was observing a boat being drawn along 'rapidly' by a pair of horses. When the boat suddenly stopped, Russell noticed that the bow wave continued forward "at great velocity, assuming the form of a large solitary elevation, a well-defined heap of water which continued its course along the channel apparently without change of form or diminution of speed". Intrigued, the young scientist followed the wave on horseback as it rolled on at about eight or nine miles an hour, but after a chase of one or two miles, he lost it

Scott Russell was convinced that he had observed an important phenomenon and he built an experimental tank in his garden to continue his studies of what he dubbed the 'Wave of Translation'. Unfortunately, the implications which so excited him (he described the day he made his original observation as the happiest of his life) were ill-understood and largely ignored by his contemporaries, and Scott Russell was remembered instead for his considerable successes in ship hull design, and for conducting the first experimental study of the 'Doppler Shift' of sound frequency as a train passes.

The 'Wave of Translation' itself was regarded as a curiosity until the 1960s when scientists began to use modern digital computers to study non-linear wave propagation. Then an explosion of activity occurred when it was discovered than many phenomena in physics, electronics and biology can be described by a mathematical and physical theory of the 'Soliton', as Scott Russell's wave is now known. This work has continued and currently includes modelling high temperature superconductors and energy transport in DNA, as well as in the development of new mathematical techniques and concepts underpinning further developments.

"I was observing the motion of a boat which was rapidly drawn along a narrow channel by a pair of horses, when the boat suddenly stopped - not so the mass of water in the channel which it had put in motion; it accumulated round the prow of the vessel in a state of violent agitation, then suddenly leaving it behind, rolled forward with great velocity, assuming the form of a large solitary elevation, a rounded, smooth and well-defined heap of water, which continued its course along the channel apparently without change of form or diminution of speed. I followed it on horseback, and overtook it still rolling on at a rate of some eight or nine miles an hour, preserving its original figure some thirty feet long and a foot to a foot and a half in height. Its height gradually diminished, and after a chase of one or two miles I lost it in the windings of the channel. Such, in the month of August 1834, was my first chance interview with that singular and beautiful phenomenon which I have called the Wave of Translation".

This event took place on the Union Canal at Hermiston, very close to the Riccarton campus of Heriot-Watt University, Edinburgh. Following this discovery, Scott Russell built a 30' wave tank in his back garden and made further important observations of the properties of the solitary wave.

Throughout his life Russell remained convinced that his solitary wave (the "Wave of Translation") was of fundamental importance, but nineteenth and early twentieth century scientists thought otherwise. His fame has rested on other achievements. To mention some of his many and varied activities, he developed the "wave line" system of hull construction which revolutionized nineteenth century naval architecture, and was awarded the gold medal of the Royal Society of Edinburgh in 1837. He began steam carriage service between Glasgow and Paisley in 1834, and made the first experimental observation of the "Doppler shift" of sound frequency as a train passes. He reorganized the Royal Society of Arts, founded the Institution of Naval Architects and in 1849 was elected Fellow of the Royal Society of London. He designed (with Brunel) the "Great Eastern" and built it; he designed the Vienna Rotunda and helped to design Britain's first armoured warship (the "Warrior"). He developed a curriculum for technical education in Britain, and it has recently become known that he attempted to negotiate peace during the American Civil War.

It was not until the mid 1960's when applied scientists began to use modern digital computers to study nonlinear wave propagation that the soundness of Russell's early ideas began to be appreciated. He viewed the solitary wave as a self-sufficient dynamic entity, a "thing" displaying many properties of a particle. From the modern perspective it is used as a constructive element to formulate the complex dynamical behavior of wave systems throughout science: from hydrodynamics to nonlinear optics, from plasmas to shock waves, from tornados to the Great

Red Spot of Jupiter, from the elementary particles of matter to the elementary particles of thought.

For amore detailed and technical account of the solitary wave, see R K Bullough, "The Wave" "par excellence", the solitary, progressive great wave of equilibrium of the fluid - an early history of the solitary wave, in Solitons, ed. M Lakshmanan, Springer Series in Nonlinear Dynamics, 1988, 150-281.

It is not generally known that John Scott Russell (1808-1882), the discoverer of the Soliton, made the first experimental observation of what is now known as the Doppler effect, and gave an independent explanation of the theory. The Doppler effect was first described by the Austrian physicist Christian Doppler (1803-1853) in 1842.
The following is a short note reprinted from the Report of the Eighteen Meeting of the British Association for the Advancement of Science, 1848, published by John Murray, London in 1849, pp 37-38.

On Certain Effects produced on Sound by the rapid motion of the observer.
By J Scott Russell, FRS Ed
Until the production of the very high velocities now given to railway trains, no opportunities have existed of observing any phenomena in which the velocity of the observer has been sufficient to affect the character of sounds. The author having had occasion to make observations on railway trains moving at high velocities, has been led to notice some very curious effects in sounds heard at 50 and 60 miles an hour. These effects are not heard by an observer who is stationary. He found that the sound of the whistle of an engine stationary on the line was heard by a passenger in a rapid train to sound a different note - in a different key from that in which it was heard by the person standing beside it. The same was true of all sounds. The passenger in rapid motion heard them in a different key, which might be either louder or lower in pitch than the true or stationary sound. The explanation of this was given as follows. The pitch of a musical sound is determined by the number of vibrations which reach the ear in a second of time - 32 vibrations per second of an organ-pipe give the note C, and a greater or less number give a more acute sound or one more grave. These vibrations move with a velocity of 1024 feet per second nearly. If an observer in a railway train move at the rate of 56 miles an hour towards a sounding body, he will meet a greater number of undulations in a second of time than if at rest, in the proportion which his movement bears to the velocity of sound; but if he move away from the sounding body he will meet a smaller number in that proportion. In the former case he will hear the sounds a semitone higher, and in the second a semitone lower than the observer at rest. In the case of two trains meeting at this velocity, the one containing the sounding body and the other the observer, the effect is doubled in amount. Before the trains meet the sound is heard two semitones too high, and after they pass two semitones too low - being a difference of a major third. There were next explained the various effects which the noises of a train produced on the ears of passengers at high velocities. The reflected sounds of a train, from surfaces like those of bridges across the line, were at ordinary velocities sent back to the ear changed by less than a tone, so as to cause a harsh discord, which was an element of the unpleasant effect on the ear, of passing a bridge. In a tunnel also the sounds reflected from any irregularities in the front of the train or behind it were discords to the sounds of the train heard directly. He showed however that at speeds of 112 miles an hour these sounds might be those

of a harmony with each other and become agreeable, for the sounds reflected in opposite directions would have the interval of a major third.

John Scott Russell's Soliton Wave Re-created

On Wednesday 12 July 1995, an international gathering of scientists witnessed a re-creation of the famous 1834 'first' sighting of a Soliton or solitary wave on the Union Canal near Edinburgh. They were attending a conference on nonlinear waves in physics and biology at Heriot-Watt University, near the canal.

The occasion was part of a ceremony to name a new aqueduct after John Scott Russell, the Scottish scientist who made the original observation. The aqueduct carries the Union Canal over the Edinburgh City Bypass.

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After a delay which would probably be unacceptable to present day funding bodies, and in a field he could never have dreamed of, Scott Russell's observations and research of 160 years ago have hit the big time in the present day fibre-optic communications industry.